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95th Congress } COMMITTEE PRINT
2d Session }

ENERGY: AN UNCERTAIN FUTURE

AN ANALYSIS OF U.S. AND WORLD ENERGY PROJECTIONS THROUGH 1990

PREPARED AT THE REQUEST OF THE

COMMITTEE ON ENERGY AND
NATURAL RESOURCES
UNITED STATES SENATE

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MEMORANDUM OF THE CHAIRMAN

To Members of the Senate Committee on Energy and Natural Resources:

Earlier this year, the committee asked Dr. Herman T. Franssen, then with the Congressional Research Service, to analyze and compare recent energy forecasts of energy supply and demand—both national and international.

Dr. Franssen's report which is now being published for the committee, provides a valuable study of these energy forecasts and makes clear the pitfalls involved in such projections. The supply and demand uncertainties, which have plagued past forecasts, seem likely to increase in the future and thereby reinforce Dr. Franssen's conclusion that such forecasting is more an art than a science.

This analysis of the strengths and weaknesses of past forecasts will, hopefully, enable us to better evaluate future forecasts and help advance the work of the forecasters themselves.

Dr. Franssen completed the final work on his analysis while on leave from the Library of Congress at the Department of Energy, where he is currently serving as Director of the Office of Market Analysis, International Affairs. Certain materials included in the study were also prepared for the Committee on Energy of the Aspen Institute for Humanistic Studies.

The committee is grateful to Dr. Franssen for his contribution to its work on energy issues.

HENRY M. JACKSON, *Chairman.*

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ENERGY: AN UNCERTAIN FUTURE

Summary

1. Energy forecasting is not an exact science; instead, it is more of an art, influenced by the Zeitgeist (spirit of the time), biases of the authors and by the inherent supply and demand uncertainties, which increase rapidly over time.

2. Energy forecasts for the United States, made in the late 1960's through the middle 1970's, used demand assumptions based on higher than average economic growth rates of the 1960's and higher than average energy consumption per unit of growth of the GNP. Hence, most of these studies project high energy demand for the period of the forecast.

By contrast, energy forecasts for the United States made in the early 1960's and the late 1970's (1977–78) used demand assumptions based on average—early 1960 studies—or below average—1977–78 studies—economic growth rates and lower than average long-term energy demand elasticity. This conforms with actual experience of late 1950's and middle 1970's; the periods preceding these forecasts. Consequently, energy demand projections in these studies tend to be lower than those made in the late 1960's and early 1970's.

3. On the supply side, the optimism of the 1960's and early 1970's as to future U.S. oil and gas discoveries has given way to generally more pessimistic oil and gas reserve additions and production projections in more recent forecasts. This trend is based primarily on disappointing finding rates. Also, the optimism of the 1960's and early 1970's on the future contribution of nuclear power has changed into a prevailing mood of pessimism.

Projections on coal use have increased in the middle 1970's largely as a response to relative energy price changes, and partly due to Government policy. Experts are still widely divided on the ability of users to burn much more coal in the United States due to clean air standards and other constraints, primarily environmental.

4. The difference between current—1978—high and low estimates of domestic oil and natural gas production is about 3 million b/d—2 MMB/D for oil and 1 MMB/D for gas. Hence, if the low projections prove accurate, the United States may have to import 3 MMB/D more than at the high production level. This is the equivalent of today's total production of Iraq.

5. While important for the more distant future, in the period through 1990 alternative energy supplies—synfuels and renewables—are not expected to make a significant contribution to total projected U.S. energy consumption.

6. While the impact of conservation and lower economic growth rates are reflected in most forecasts, the combination of lower energy demand growth rates with lower domestic production projections has

resulted in little change in estimates of U.S. dependence on foreign oil imports in the 1980's. Most studies still estimate U.S. oil imports in 1985 at between 10.5 and 11.5 million b/d.

7. The level of world oil demand is driven by three principal variables: Economic growth, demand elasticity—conservation—and interfuel substitution. Energy forecasts published in the past few years show differences in long-term OECD economic growth rate—through 1985–90—of about 0.5 percent annually. This difference in economic growth rates alone could result in additional—or less—demand for energy in the free world of up to 13 million b/d oil equivalent by 1990.

Energy forecasts in recent years also vary in their assumptions of the future role of conservation. A difference of 10 percent in the free world conservation outlook—energy to GNP growth ratio—translates into an oil equivalent of up to 9 million b/d oil equivalent by 1990.

Interfuel substitution: The difference between low and high free-world natural gas production in recent studies is about 2 million b/d oil equivalent; with most of the difference in estimates related to U.S. production. The difference between high and low free-world estimates of coal and nuclear energy are respectively 2 and 1 million b/d oil equivalent. Most of the difference in the coal use estimates is again related to uncertainties in the United States.

Outside the United States, nonoil energy supply estimates in most recent studies are almost too close to be credible. While the margin of uncertainty may be highest in the United States, there is a fair degree of uncertainty concerning the future contribution of natural gas and nuclear power elsewhere in the free world. This uncertainty is not sufficiently expressed in most recent world energy forecasts.

8. There are also differences between the various studies on free-world, non-OPEC oil supplies. Seven recent—1978—studies show OECD oil production ranges between 15.7 to 17.3 for 1985 and between 14.5 and 19.1 for 1990.

Ranges of non-OPEC LDC production in the same studies are between 7.5 and 8.9 million b/d for 1985 and between 8.1 and 11.6 million b/d for 1990. It is interesting that the low OECD production estimates are matched with high non-OPEC LDC production projections, and some of the high OECD production estimates are matched with low non-OPEC LDC production projections. Hence, the difference in total free-world non-OPEC oil production estimates between the low and high estimates in the seven recent studies is only 1.7 mmb/d in 1985 and 3 mmb/d by 1990.

A difference in estimates of 1.7 mmb/d is the equivalent of Indonesia's maximum sustainable production; the 3 mmb/d difference in 1990 forecasts is equal to the current maximum sustainable capacities of Iraq or Kuwait, or about 0.7 mmb/d higher than the maximum sustainable capacity of either Libya, Nigeria, the United Arab Emirates or Venezuela.

9. Recent estimates of the net oil import or export position of the centrally planned economics—U.S.S.R., Eastern Europe, People's, Republic of China, Yugoslavia, Cuba, North Korea, North Vietnam. Laos, Cambodia, and Albania—range from CPE exports of 1 mmb/d in 1985 to net CPE imports of about 2.5 mmb/d.

The difference between the low and high CPE import estimates translates into an addition demand for OPEC oil ranging from—1 to 3.5 mmb/d. The latter again corresponds with the total current sustainable capacity of Iraq.

10. As a result of different estimates of free world, non-OPEC demand and supply and future perception of CPE energy developments, there are considerable differences in projections of world demand for OPEC oil. Estimates of demand for OPEC oil in seven recent studies, which are representative of all different views in Government and corporate circles, vary between a low of 35.5 and a high of 48 mmb/d for 1985 and between a low of 35.5 and a high of 58.4 mmb/d for 1990. The high estimates however, assume that OPEC countries will be able or willing to produce more than between 36.8 and 41.0 mmb/d in 1985 and between 36.5 and 43.5 mmb/d by 1990.

The high estimates are based on constant prices. With demand for OPEC oil rising above sustainable production, prices in the high estimates are projected to rise in real terms.

11. Several variations of world oil demand, non-OPEC oil supply, CPE oil imports (or exports), and OPEC production possibilities have been analyzed in order to project possible oil-pricing scenarios. Of the 13 scenarios developed, 2 show very substantial world oil price increases of up to $31.50 per barrel (in 1978 dollars) in the 1985–90 period. Three scenarios assume high world oil demand, low OPEC and non-OPEC supply, and high CPE oil imports. Three other scenarios show no price increase at all (in 1978 dollars). These assume generally low oil demand; low OECD, non-OPEC LDC, and OPEC oil supply; and low net CPE oil imports.

Eight of the thirteen cases show moderate to substantial oil price increases to between $16 (again in 1978 dollars) and $23 in 1985 and $17.50 to $24 by 1990.

CHAPTER I—ENERGY FORECASTING: AN UNCERTAIN ART

Since the Arab oil embargo of 1973–74 a plethora of domestic and international energy forecasts by public and private organizations have been issued. Some were based on elaborate econometric models, and others were primarily judgmental studies. To the policymaker the conflicting outcomes of the findings of the various known studies have been rather confusing. There were wide variations among those various estimates of U.S. world energy demand and supply for the next 10 to 25 years. A discussion of the main differences in assumptions and findings of some recent studies will follow elsewhere in this chapter.

Energy forecasters are constrained by numerous uncertainties, biases, and by the zeitgeist (the spirit of the time).

ZEITGEIST

Much of the late 1950's and the 1960's were characterized by prevailing optimism about the future. The Western World was in the midst of a prolonged economic boom, which was in part spurred by unprecedented technological innovation. The era of growth and continued improvements in personal wealth was expected to continue for decades to come (Herman Kahn), and resources constraints or limits to growth were not yet considered to be issues of great importance.

In energy developments, technology had enabled man to capture the atom for power generation at prices which were then estimated to be "too cheap to meter." Oil and natural gas reserves in the United States were added annually in quantities sufficient to meet demand, and coal—the dirty fuel—was expected to be on its way out.

Beginning with the Vietnam war and the widespread public acceptance of the environmental movement, technology, economic growth, and energy development were reexamined. The Club of Rome's "Limits to Growth," Paul Ehrlich's "Population Bomb," and numerous books on the evils of unrestrained technological development and economic growth signaled the beginning of the new era of pessimism in the Western World. Many observers agree that the West has not known such widespread cultural pessimism since the post-World War I era when Spengler's "Undergang des Abendlandes" was widely read.

Energy forecasters like everybody else are influenced by such changing moods. In the 1960's, energy forecasts reflected the prevailing optimism of the time on the future of the world economy, oil and natural gas resources, and the prospects of nuclear power development. Today, energy forecasts reflect doubts about the ability of the Western World to maintain economic growth rates at levels required to prevent unemployment from rising any further. Furthermore, fears about early exhaustion of petroleum resources and concern about the potentially ecologically disastrous effects of nuclear power and possibly also coal use have cast doubts about our ability to solve the problem of shifting from oil to other energy sources. It is possible, even likely, that the zeitgeist will change again in the future and that pessisism about the future will once again make place for more optimistic prospects. Until that happens, energy forecasts are likely to reflect the pessisism of our time.

UNCERTAINTIES

One can say with a fair degree of accuracy that energy developments are going to be more uncertain in the future than they have been in the past. This is only in part related to our lack of information about oil and gas resources and actual annual additions to reserves.

Among the uncertain variables affecting U.S. and world energy demand and supply are:

—The performance of the U.S. and world economy. While energy prices have some affect on economic growth rates, there are numerous other factors affecting economic growth. The performance of the economy is one of the key variables for determining future energy demand. While the long-term relationship between economic growth and energy consumption is not clear, there is definitely a link between the two phenomena. A recent Exxon study suggests that 0.5 percent change in free world GNP growth rates (upward or downward) could increase or reduce energy demand by 13 MMB/D oil equivalent between 1978 and 1990.

—Demand elasticities, or the changes over time of the volume of energy needed to produce an additional unit of GNP. Variations in the energy/GNP ratio have been significant in the United States during the past quarter of a century, but the general long-term trend (1920–78) has been one of less energy consumption per additional unit of GNP. This happened under declining real prices for energy, and it would not be unreasonable to assume that this trend will continue in the future when the real price of energy is projected to rise. In other countries experiences have been similar, and although expectations of energy conservation differ widely from country to country, it is generally accepted that the energy/GNP relationship is subject to further adjustment under increasing real prices.

The principal difference of view between energy forecasters is confined to the degree of demand elasticity under a scenario of rising prices. The difference, however, between a free world energy multiplier (energy growth rates divided by economic growth rate) of 0.9 or 1.0, for example, translates into an additional free world demand of almost 9 million bbl/d of oil equivalent between 1976 and 1990.

—Total oil and natural gas resources, and the rate of reserve additions over time. The consensus view of ultimate recoverable world oil resources—expressed by petroleum geologists such as Moody, Hubbert, Weeks, and others—holds that about 1 trillion barrels of oil are still to be discovered around the world. Most of these resources are expected to come from extensions of existing fields, additional production from existing fields with advanced recovery techniques, smaller fields and/or accumulations in hostile physical environments. While some geologists are more optimistic and others more pessimistic than the consensus view, the key question is not so much how much oil will ultimately be found, but how much will be added annually to reserves. In the United States, for example, those who are projected a production of up to 12 million bbl/d by the middle 1980's must assume that between now and 1985 the United States will add about twice as much to reserves annually as it did during the past decade.

On a worldwide scale, projections of reserve additions run from 10 to 20 million barrels per year. In spite of significant improvements in geophysical exploration techniques, oil exploration is subject to a great deal of uncertainty. Optimists argue that higher prices and subsequent higher drilling activity on a worldwide scale will lead to reserve additions averaging close to 20 billion per year. Pessimists maintain that most large basins have been found and that most new finds in the future are likely to be relatively small.

FLOW RATES

Oilfields around the world have different reservoir characteristics, resulting in different flow rates. Moreover, the economics of oil production differs widely, making it difficult to make generalizations on oil production even on the basis of existing reserves. The United States, for example, produces about 10 million bbl/d of oil from 39 billion barrels of reserves. Iran, with about 60 billion barrels of oil reserves, is not likely to be able to produce more than 6.5 million bbl/d from its larger reserves.

ENVIRONMENT

Uncertainty about domestic and foreign regulations to protect the environment can lead to postponement or abandonment of energy developments. Concern about the environmental effects of offshore oil and gas production has slowed down the search for and development of petroleum in the United States and a few other countries. Environmental concerns about nuclear powerplant siting and the fuel cycle have resulted in prolonging the licensing process, adding considerable costs and uncertainties about the future of nuclear power in the United States and other OECD countries. While the upper limit of the contribution of nuclear power in the OECD countries is pretty well established for the middle 1980's, further cancellations and/or construction postponement are still possible, and developments beyond the middle 1980's are still very uncertain.

The future of coal use, on which the current administration has based much hope, is by no means assured. Uncertainty about the compatibility of clear air standards with increased coal use; a myriad of other environmental and institutional problems related to expansion of coal consumption; potential transportation and production bottlenecks; and, last but not least, the unknown effects of CO_2 on the atmosphere, all contribute to significant differences of view on U.S. coal use in the future.

Other probably less serious environmental problems related to the development of most other domestic and foreign energy sources, further add to the domestic and foreign supply uncertainties.

GOVERNMENT POLICY CHANGES

Different administrations have followed different strategies on energy demand and supply, and on issues directly or indirectly inpacting on energy developments. Leasing of Federal lands for mineral developments; strengthening of environmental, health, and safety regulations; shifts in R. & D. policy; and a complete review of nuclear power programs are but some of the major changes that occurred in recent years. Energy forecasters have difficulty identifying future changes in Government policy under different administrations.

Energy supply and demand decisions made by other governments are equally uncertain. Scholarly explanations of current and future OPEC cartel behavior from particular disciplinary vantage points are by no means in agreement. Some view OPEC as a cartel of businessmen whose actions are almost exclusively guided by the principle of profit maximization, while others maintain that OPEC decisions are based on a mixed bag of political and economic criteria. OPEC analyst also disagree on purely technical issues such as productive capacity and production investment decisions. Different perceptions of the behavior of OPEC and its national components have led to variations in production projections by energy forecasters.

TECHNOLOGICAL INNOVATIONS

Technological innovation can have a very significant impact on energy projections, and in particular on long-term forecasts. Optimism about technological advances in recovery of nonconventional natural gas in the United States for example, has caused some energy analysts to project a total contribution of natural gas of between 25 and 35 trillion cubic feet by the end of the century. Others, who are less optimistic about technological innovation and the resource base, maintain that no more than 10 to 15 trillion cubic feet of natural gas can be counted on.

Optimism or pessimism about advanced recovery of oil—conventional or nonconventional—techniques to burn coal in an environmentally acceptable way, a fail-safe nuclear fuel cycle, a breakthrough in solar technology, all impact substantially on energy forecasts.

Related to this issue is the degree of optimism or pessimism of energy forecasters concerning leadtimes between technological innovations and full commercialization of the new technology.

CENTRALLY PLANNED ECONOMIES

The Central Intelligence Agency issued a publication last year, projecting a serious shortfall in Soviet oil production in the 1980's. The study was based on painstaking analyses of Soviet documents, Soviet purchases of oil drilling equipment in the West, and other sources of information. The study has been revised a number of times but the central theme still reveals a rather pessimistic view of Soviet ability to continue expanding oil production in the 1980's. The CIA believes that the Soviet bloc—U.S.S.R. and Eastern Europe—together with most other centrally planned economies—except the P.R.C.—are likely to import up to a few million barrels per day of oil by the middle 1980's.

The study was met with disbelief in many circles. While few, if any, have undertaken an equally exhaustive study of Soviet energy developments, those who disagree with the CIA analysis do so mainly because they believe that the Soviet bloc—already heavily indebted—cannot finance several million barrels per day of oil imports.

All these and possibly other uncertainties are frequently resolved by resorting to calculated guesses by those responsible for energy projections. The uncertainties, however, may prove to be a convenient scapegoat to hide the forecaster's biases.

BIASES

Many energy forecasters whose studies receive front page coverage in the Nation's leading newspapers use the uncertainties discussed above to inject their own biases to "prove" that their view is most likely correct. Very few—if any—forecasters are without biases, and if the reader is aware of the forecaster's views or sentiments, he can adjust the projections based on his own knowledge of the subject matter.

The real danger of the forecaster's biases lies with the less informed reader, who may adopt the forecasters biased assumptions as scientific truth. Unfortunately, energy forcasting is subject to so many uncertainties, that the forecaster can easily hide behind quasi-empirical analyses.

—The impact of conservation measures and price on energy consumption. Those who are worried about the potential adverse environmental impact of additional energy supply options, are likely to show "proof" of lower future economic growth rates and a significant improvement of the energy/GNP ratio.

On the other hand, those who want proof of the growing gap between indigenous supply and demand, may use data from the past to show that potential savings will be largely offset by countervailing forces and that long-term economic growth rates and energy demand elasticities will not differ much from past trend forecasts.

—Large and small oil and gas companies alike need to be optimistic on the oil and gas option, because without it their future growth is seriously impaired. In their past forecasts many oil and gas companies have been overly optimistic in projecting domestic oil and gas discoveries, brushing aside the experience of half a century of reserve additions. The same can be said about entrepreneurs engaged in research to find an economic way of developing nonconventional oil or gas resources. Governments are generally more pessimistic in their assessments, in part because they have to build in a safety margin in their future energy supply and demand forecasts. Oil companies plan for future opportunities; governments plan for limiting uncertainties.

In their enthusiasm for nuclear power development or the coal option, advocates have frequently shown the technical potential of the industry, without carefully examining the numerous economic, environmental, and institutional constraints on the development of their favorite energy source.

On the other hand, those who do not like the nuclear and/or the coal option, may show that between increased prospects for oil and gas production, conservation, and solar development, much of the future energy supply problem will be solved. One recent domestic energy forecast by a respected Government agency projected very low total U.S. energy consumption by the end of the century, coupled with an increase of solar power to one-quarter of total energy consumption.

—Econometricians have at times gone overboard in their analyses of price elasticity of supply. The Ford Foundation study of 1974, studies by McAvoy of M.I.T. on natural gas, FEA's Project Independence on future oil and gas projections, and many other studies were overly optimistic on the impact of higher prices on U.S. oil and gas supply. Engineers, on the other hand, have looked at technical fixes, often regardless of the impact of price changes on supply. Political scientists frequently ignored both price and technology, and put forward their own theories of political solutions to all energy problems.

—Related to pro-Arab or pro-Isreal sentiments are studies which set out to "prove" that a total surrender to perceived political and security needs of either party in the Middle East conflict will be most beneficial to U.S. national security. Some maintain that technical and economic criteria determine Arab attitudes toward oil production and pricing, and that politics only plays a marginal role. This school of thought generally projects oil production of OAPEC surplus countries far above what those countries are currently planning to produce in the future. Those who oppose the administration's even-handed policy in the Middle East also tend to show great optimism about oil reserve additions in non-OPEC countries; emphasize large scale inter-fuel substitution; and project rather low energy growth rates. Such a scenario would "prove" that cooperation with OAPEC countries is not a necessary prerequisite to the maintenance of adequate oil supply at acceptable prices.

It is unescapable that energy forecasters—like other mortals—are captives of the "Zeitgeist" and their own particular biases. It is unfortunate, however, that given the many uncertainties in the assumptions underlying the forecasts, policymakers and the public at large are bombarded with an ever-growing volume of domestic and international energy studies of different quality and scope, without having the ability and stamina to evaluate the strengths and weaknesses of everyone of the analyses. Aside from the biases and uncertainties, the state of the art of energy forecasting has not much advanced in recent years.

In the early sixties growing optimism about the ability of economists to manage the economy and avoid business cycles, led some to believe that all that was left for the professionals was to "fine-tune" this process. Our current inability in the Western World to cope with inflation and growth, indicates that the early optimism about the art—or did we believe it was a science?—has been dampened. Energy forecasters, whether they are complex model builders or more traditional "judgmental" analysts, are even further away from "fine-tuning" their energy projections. We must get used to living with and planning for growing uncertainty about our energy future, while continuing to improve our analytical tools.

FORECASTING TECHNIQUES [1]

1. *Advantages and limitations of mathematical modeling as applied to energy analysis and forecasting*

Definition of terms

Modeling is the process of representing a complex system by a simpler system. The abstracted simpler system is called a model. Such a process is a necessity for analyzing and understanding any but the simplest of real world processes. Such understanding is basic to forecasting the probable form of the real world processes.

Mathematical modeling merely defines one form of this abstraction process. This form is a series of mathematical expressions relating the major variables in some quantifiable, functional form. This quantified specification of the relationships is in one way more limiting than the more qualified relations that an analyst may model nonmathematically; that is, an abstract notion in his brain of the interrelationships of the variables. On the other hand, with the computer capability of managing complex equations and huge data bases, a mathematical model can potentially account in greater detail and, therefore, abstract from the real world with greater fidelity than otherwise could be done.

Mathematical modeling has evolved into several distinct lines of modeling methodology. Econometric modeling is one major line of effort. It is the abstraction from the real world in economic terms, by prices and dollar flows. Econometric modeling can be used to represent the functioning of the entire economy with such as input-output analyses; for example, Wharton, DRI, Chase models, and many others or focus only on the energy transactions of the economy or just a sector of the economy. Process modeling—or engineering modeling—is another major line of effort which abstracts from the real world in physical flows. Such models can represent a firm, an industry, or a process or processes in the economy. Eclectic modeling is the combination of various process and econometric models to form the representation of an entire system.

Models may be static, essentially snapshots of an equilibrium at a point in time. Or, models may be dynamic, essentially driven incrementally over time by their prior state. Models may be designed to be optimizing, whether as least economic cost, energy cost, capital cost, etc. Or, models can be designed to follow other market or institutional rules.

Advantages of models

The explicit representations of models and the need to quantify each element to be represented force the analyst to examine his assumptions carefully and to test them against the real world data from which he has abstracted. The process often reveals structures and relationships which may not be readily apparent. Or, a widely held assumption may be shown not to be provable.

While a model cannot forecast without being initiated by the analyst or fed exogenous states by the analyst, its representation of the future insures a consistent set of results by the model. This consistency may reflect only mathematical consistency in an accounting sense and the extent that it represents the real world consistently is dependent on whether the model mirrors the essential real world elements sufficiently accurately. In the complex energy systems of interest, it is difficult to insure that judgmental forecasts imply consistent results of all sectors. Therefore, modeling is a decided advantage in this sense.

---

[1] This section on forecasting is from an unpublished 1976 study of the National Petroleum Council.

With modeling, it is relatively easy to test a number of assumptions, and it is particularly useful to see how these assumptions affect the outcome of the modeling results. It is difficult to test the fine structure of such changes without the use of mathematical models.

Limitations of models

No matter how complex the model is itself, it will not be the real world. It is by definition a simplified abstraction. While useful for analysis, it does not insure, per se, realistic solutions. Relationships of future importance may not be included, because they are not now recognized, or relationships of importance in the past may no longer be driving forces in the future.

A model may be solely based on historical or cross-sectional data. As a forecasting tool, the model results are then dependent on the relationship in the future being the same as in the present or the rate or change being the same as the historical period used to derive the model. This is particularly important when events in the forecast are expected to vary significantly from the range of values upon which the model is derived. For example, there is great concern whether price elasticities derived historically have much predictive value when relative prices increase twofold or more.

Alternately, a modeler can insert changing relationships to reflect his opinion of important future trends. But this differs from judgmental forecasting merely by the mathematical representation of the event or relationships.

Perhaps the biggest limitation of mathematical modeling is that the model user and the modeler misperceive the results of modeling exercises. Because of the mathematical precisions of the results, there is a tendency to assume that they necessarily are an exact representation of what will happen in the future.

Energy modeling forecasts

Forecasts derived from models result in a consistent set of results as defined by the model. This, however, does not necessarily reflect any more accurate a picture of the future than forecasts based solely on judgment of the analyst. Like the judgmental forecasts, mathematical models are based on the decisions of the modeler and the abstraction he has drawn of the real world.

Their most valuable characteristic is the explicitness necessary in deriving the model. This means that by studying the model, one can understand what assumptions created the results and how changing some of the assumptions affects the results of the projections.

2. Judgmental—Eclectic forecasting

The "judgmental-eclectic" approach to economic forecasting simply means the forecaster takes into consideration all the factors—historic current, and anticipated—he can assimilate in arriving at his judgment of the future course of the economy or level of economic activity. This includes as much historic data, current developments, political trends, behavioral patterns, etc., and intuition based on knowledge and experience, as is possible to be assimilated. Admittedly the word "judgmental" implies that there will be a subjective element involved in such forecasting, but the forecaster attempts to minimize this element by striving toward objectivity in analyzing and interpreting information at his disposal.

Judgmental forecasting is not exclusive of econometric or other modeling techniques. Model inputs and results are useful to the judgmental forecaster in that they provide a reference point and contribute to his assimilation of many variables.

The principle of econometric/mathematical forecasting has long been known to economists—particularly since the work of Stanley Jevons and Leon Walras. The Walrasian general equilibrium equations have not been disputed in theory; that with a sufficient number of simultaneous equations (actually an infinite number) one could solve for the many "unknows" in the market/price system. With the advent of computers and advances in mathematics this principle has been applied in econometrics.

However, the judgementalist would argue that no practical model can contain a sufficient number of equations to provide accurate answers. Second, he would argue, a model is inherently static in that it can reflect only historic relationships that it then projects to the future. Third, he would argue the statistcal data inputs lack sufficient cardinal preciseness and at best are only ordinal measures of economic activity. Fourth, the judgmentalist would contend that since econometric models are based on historic relationships, then the use of a model to forecast is a judgmental assumption that ignores current developments and future shocks to the economy. Fifth, if the model is adjusted for these current events and shocks (such as the oil embargo) then the model is a mathematical manipulation of judgmental assumptions. Sixth, there are many factors that affect economic decision-making that cannot be quantified; either the model must assume certain relationships for these factors or ignore them, which means the model must either be judgmentally based or incomplete.

Econometric models can forecast only in the sense that they can assume that relationships or trends which existed during a historic "simulation" period will continue into the future. Due to the problems of data availability and the timelag of preparing a model, this simulation period often must end 1 or 2 years or more prior to the current period. This particular weakness of models resulted in serious forecasting errors in 1973 and 1974. The modeling timelag can be reduced in those cases where the existing model structure remains satisfactory, and the updating process involves only reestimating model coefficients using newly available historic statistics.

A serious potential problem associated with models is that their complexity and appearance of precision may encourage users of the models's output to exaggerate the accuracy of that output. While this problem tends to be most acute when the users are not familiar with modeling techniques and limitations, it can sometimes arise even when users are experienced modelers.

In contrast, judgmental techniques are often discounted because of their lack of preciseness, and the difficulty of explaining to the user the logic associated with the intuitive parts of a judgmental forecast. In these cases it is the reputation, or "track record" of the forecaster which will determine the confidence with which judgmental forecasts are used.

The studies analyzed in the next chapter represent both energy forecasts based on mathematical models and on the so-called judgmental-eclectic approach. A few are in part judgmental and in part based on mathematical modeling.

CONCLUSION

The track record of most long-term energy forecasts has not been very good, and it is questionable if energy forecasting in the near future will prove to be a more accurate barometer of our energy future. While several universities and government agencies have developed elaborate mathematical models to project energy demand, supply and prices, energy forecasting is still more of an art than a science. In fact, the track record of judgmental forecasts has generally been more accurate than most of the available mathematical models.

There is little doubt that energy forecasts are influenced by the Zeitgeist. The prevailing outlook of the future of the United States and world economy; the ability of technology to influence both demand and supply of energy; the extent of the liquid hydrocarbon resource base, and the ability of countries to cope with environmental problems, all impact on energy projections.

During the 1960's when economists thought that all that was left for economists was to "fine-tune" the economy and when technological progress in the United States made European heads of state believe that the United States would remain forever the master of modern technology, energy forecasters were generally very optimistic about the ability of the country to meet rapidly increasing energy demand from a variety of conventional and nonconventional sources. The current prevailing atmosphere of pessimism has caused growing doubts among energy forecasters about the ability of the Nation (and the other OECD regions) to meet even our sharply reduced energy demand by the middle or late 1980's without potential serious economic and/or environmental side effects.

The inherent uncertainty in long-term economic forecasting, the impact of conservation, and the numerous domestic and international energy supply uncertainties, has resulted in a plethora of energy forecasts, which, on the surface, may be equally credible. Acceptance of the key ingredients of energy forecasting is subjective, but any one or combination of demand or supply assumptions can have a major impact on energy pricing.

Hence, if a forecaster assumes that OPEC will expand sustained productive capacity substantially and make it available when needed in the future, the near and intermediate future may not include a significant real price increase. Also, if one assumes that the free world economy will continue to grow at rates substantially below what is needed to maintain current rates of employment, the near and mid-term future may also not include a significant real price increase.

In chapter V on "World Oil Demand and Supply Through 1990," we have attempted to spell out many of the demand and supply uncertainties related to oil developments. There are many additional uncertainties related to nonoil developments in the United States and abroad. Due to physical and human phenomena subject to surprise and frequent change, it is understandable that different projections of energy demand, supply, and prices can all be believable at the same time.

The policymaker is, no doubt, aware that energy forecasters work for different clients, and that, for example, oil companies plan for future opportunities, while governments have to plan for national supply security.

Chapter II—U.S. Energy Forecasts: An Overview

An examination of U.S. energy forecasts undertaken by various organizations over a period of almost two decades, tends to confirm the view that forecasters are generally captives of the "Zeitgeist." They tend to base their projections for the future on recent experiences.

ECONOMIC GROWTH RATES

Most energy forecasts throughout the 1960's and early 1970's projected U.S. long-term annual economic growth rates at close to 4 percent, the average growth rate estimated to be required to maintain full employment. Studies undertaken in the early 1960's are generally a little less optimistic about future economic growth rates, which may reflect the lower than average performance of the U.S. economy in the late 1950's, After the early 1970's, when new data pointed in the direction of a slowdown of both population growth rates and labor productivity in the United States, energy forecasts reflected the new view. Most recent studies project U.S. economic growth rates throughout the 1980's at 3.2 to 3.5 percent per year. Between 1950 and 1976 economic growth rates in the United States averaged 3.4 percent per annum.

ENERGY DEMAND

Energy demand is a function of economic growth and energy elasticity. The latter is generally measured in the aggregate by dividing annual energy growth rates by GNP growth rates. In the past 50 years the ratio between energy and economic growth rates in the United States has declined steadily. The period from 1930 to 1945 or 1950 shows a very steep decline in this ratio, while successive periods of 5 years from 1950–75 show erratic upward and downward movements of demand elasticity curves. The average energy/GNP ratio (the multiplier) over the entire period from 1950 to 1975 was 0.9; that is, for every unit of GNP growth, 0.9 units of energy—measured in Btu's—were needed. Within this period of a quarter of a century, the multiplier behaved as follows:

TABLE 1.—THE ENERGY MULTIPLIER

	Multiplier	Economic growth rates
1950–55	0.63	4.3
1955–60	1.1	2.2
1960–65	.81	4.8
1965–70	1.45	3.2
1970–76	.65	2.1

The averages are reflected in energy forecasts made in those same years. The few studies quoted here from the early 1960's project a continuation of the trend of the late 1950's, while studies undertaken in the late 1960's and early 1970's project a multiplier more in line with the experience of the early and middle 1970's, when the multiplier was as low again as it was in the period from 1950 through 1955.

TABLE 2.—FORECASTS OF U.S. ENERGY DEMAND, 1960–78

[In quads]

Study	Base year	GNP growth rate	Energy growth rate	Multiplier	1980	1985	1990	2000
AEC (1960)	1953				86.2			170.0
SICC (1962)	1961	3.5–4.5	3.3	0.82–0.93	82.0			
BOM (1962)	1947–62				85.9			
NAS (1962)	1907–60				[1] 61.0			
RFF (1963)	1900	3.0; 3.8; 4.8	2.8	.9; .7; .6	79.2			135.2
AMS (1966)	1900	3.5	3.1	.9	90.3			174.0
	1900	4.0	3.6	.9	99.7			213.0
SC (1967)	1960–65	4.6	4.8	1.0	93.3	118.1		
BOM (1968)	1497–65	2.5	3.8	1.5	88.1			168.6
	1954	4.0	3.8	.9	83.9			158.9
CMB (1968)	1965				97.0			
TETC (1968)	1947–65	5.0	4.8	1.0	97.8	119.6		
WEM (1970)	1947–69	4.0	4.8	1.2	95.1		134.7	168.0
RFF (1971)	1900–69	4.0	5.1	1.3	95.1		134.7	190.0
NPC (1971)	1960–70	4.2	5.6	1.3	102.6	124.9		
FPC (1971)	1970	4.0	4.2	1.1	105.0		142.0	
NOC (1971)	1971	3.0	3.9	1.3	101.6			
DOI (1972)	1970	4.3	3.3	.8	96.0	116.6		191.9
FPC (1973)	1970	4.0	3.1	.8	94.1	114.9	143.4	202.6
NPC (1973)	1970	4.2	3.9	.9		124.9		200.0
Ford (1974)	1970	3.5	1.9	.55		91.3		124.0
		3.5	3.4	.9		116.1		186.7
FEA (1974)	1970	3.5	2.7	.84	68.3	102.9		
H&T (1975)	1970	3.8	2.9	.7	90.4	105.8	122.9	163.4
FPC (1975)	1970	4.0	3.6	.9	95.3	115.4	140.5	
BOM (1975)		4.1	3.3	.8	87.0	103.5		163.0
Exxon (1975)		3.7	2.7	.7	84.4	96.8	113.4	
Shell (1975)		3.1	3.0	.9	86.0	99.6	114.4	

[1] Minimum.

	GNP growth rate	Energy growth rate	Multiplier	1980	1985	1990
Pace (1976)	2.6	2.5	.9		99.7	
Bankers Trust (1976)	4.2	3.2	.75			
W. J. Levy (1976)	4.6	3.5	.87		103.0	
Shell (1976)				88.0	101.8	116.8
Exxon (1977)	3.5	2.8	.8	86.4		115.0
Lichtblau (1977)	3.5	2.4	.7	82.4	92.9	103.1
CIA (1977)	4.3	3.8	.9	88.9–91.2	102.0–106.7	
OECD (1977)	3.9	3.2	.8	84.3	99.9	
CRS (1977)	3.4	2.9	.8	84.6	94.8	108.9
NEP (1977)						
WAES, D (1977)	3.4	3.2	.9			
EIA (1977)	4.1	2.9	.7		94.6	
Lichtblau (1978)	3.5	2.5	.7		95.3	
SRI (1978)	3.4	2.8	.8		93.4	
Mobil (1978)	3.8	2.9	.76		96.3	

In reality, long-term economic growth rates from 1950–75 have been considerably below the projected percent 4 of most forecasts—1950–75 U.S. economic growth averaged 3.4 percent per year—and the multiplier over that same period averaged 0.9. A few studies undertaken in the early 1960's ,which happen to reflect this average, now appear to be closer to current energy demand forecasts for 1980 and 1985 than studies made in the early and middle 1970's, which reflect the higher economic growth rates and the higher multiplier of the late 1960's (see table 2).

It is not clear why there were such differences in the energy/GNP relationship during the 1950–75 period, but there are some partial explanations, such as:

—Changes in the business cycle. At times of higher economic growth, the multiplier tends to be lower, reflecting more efficient use of energy. During periods of lower economic growth the multiplier tends to be higher, reflecting less efficient use of energy;

—The sharp decline in energy use during the 1974–75 recession, which hit hardest in the industrial sector of the economy—underutilization of industrial capacity;

—Higher prices and mandatory conservation policy in the post-embargo years;

—The very high multiplier of the 1965–71 period could be partially explained by the rapid trend toward electrification of new homes; the increase in the average size of homes and number of appliances per dwelling, and rapidly expanding installation of air-conditioners in new and existing homes. Furthermore, cars were becoming less energy efficient due to size, weight, additional power features, and environmental protection equipment.

It is difficult to project the extent to which mandatory conservation and prices will improve the energy/GNP ratio in the United States, other OEDC countries and some developing nations in the future. The historical long-term—1950–75—energy/GNP ratio of 0.9 to 1.0 in the United States is likely to decline due to rising prices and mandatory conservation measures, but some of the potential savings are likely to be offset by the further trend toward electrification, development of lower grade ores, and energy needed to reduce pollution.

Most recent forecasts assume a reduction in the multiplier from 0.9—1950–75—to between 0.7 and 0.8 throughout the 1980's.

Of the 40 forecasts of U.S. energy demand and supply—in table 2—about half were made before the 1973–74 quadrupling of the price of world oil; the other half were completed after the price jump.

As previously indicated, shifts in perceptions of the future performance of the U.S. economy and reevaluation of energy demand elasticity following the 1973–74 oil price jump, have had a profound impact on the outlook of future U.S. energy demand.

While there is no sufficient proof that energy forecasters are the captives of the "Zeitgeist," table 1 shows some relationship between the actual performance of the U.S. economy and energy demand elasticity in the years immediately preceding the forecasts, and the forecasts made at the time.

For example, the United States went through a period of slow economic growth in the second half of the fifties and early sixties, while the multiplier during thst period was close to the long-term average of 0.9. This is reflected in the forecast made in the early 1960's (see table 2). The period of the middle and late 1960's, by contrast, was characterized by higher than average economic growth rates and a multiplier of 1.45 (i.e., 1.45 units of energy were needed to produce an additional unit of GNP). Again, table 2 shows that the actual experience of the Nation's economic performance and energy demand elasticity was reflected in the forecasts made at that time.

The most recent period examined—the early to middle 1970's—again shows lower than average economic growth rates and a multiplier of only 0.65. In some ways, the combination of the low economic growth rates and low multiplier of the middle 1970's, is reminiscent of the period of the late fifties.

As a result, energy demand projections made in the early 1960's are more in line with recent projections for the 1980's than projection made in the late 1960's and very early 1970's. The latter were based on more optimistic estimates of the future performance of the economy and more pessimistic projections of demand elasticity.

RECENT ENERGY FORECASTS, 1974–78

Tables 3 and 4 and figures 1 through 9 provide more detailed forecasts of U.S. energy demand and supply undertaken by various organizations between 1974 and 1978.

TABLE 3.—U.S. ENERGY DEMAND PROJECTIONS FOR 1980–90 VARIOUS FORECASTS SINCE 1974

[In million barrels per day oil equivalent]

Title	Year under taken	Agency	Energy consumption projections		
			1980	1985	1990
A Time To Choose	1974	Ford Foundation	42.5	44.9	
Project Independence	1974	FEA ($11 B/C)	40.8	48.6	
U.S. Energy Prospects	1974	NAE		49.2	
CTAB Recommendations for a National Energy Program.	1975	Commerce		51.0	
U.S. Energy Through the Year 2000	1975	BOM	41.2	48.9	
An Assessment of U.S. Energy Policy	1976	Levy		48.9	
National Energy Outlook	1976	FEA	[1] 38.6	46.7	54.8
			[2] 40.3	48.8	57.5
Towards Project Interdependence	1975	CRS (B/C)	41.6	47.7	
World Energy Outlook	1977	OECD (B/C)	40.5	48.1	
U.S. Energy Outlook	1977	CIA	42.0–43.1	48.2–50.4	
Do	1977	Exxon	40.8	45.5	51.5
Do	1978	do	40.5	44.9	51.0
Do	1977	Shell	41.6	48.1	55.2
Do	1978	do	40.2	45.1	50.6
Workshop on Alternative Systems	1977	MIT (C)		43.5	
		MIT (D)		44.6	
National Energy Plan	1977	Executive Office of the President.		46.4	
Projections of Energy S. & D. and Their Impacts.	1978	EIA (medium case)		(3)44.7	(2.5)51.3
				(3.2)[3] 45.8	(2.8)51.7
Technical Analysis of the International Oil Market.	1978	Frankel	40.9	46.5	51.5
World Energy Model	1978	SRI	39.9	44.1	49.0
Project Interdependence	1978	CRS	40.4	45.1	51.5
Outlook for World Oil Into the 21st Century	1978	Lichtblau (B/C	39.9	45.5	50.6
	([4])		38.6–43.1	43.5–51.0	50.6–57.5

[1] $13.

[2] $8.

[3] High.

[4] Range.

TABLE 4.—U.S. ENERGY SUPPLY PROJECTIONS FOR 1980–90 VARIOUS FORECASTS SINCE 1974

			Domestic Supply																	
			Oil (million barrels per day			Natural gas (trillion cubic feet per year)			Coal (million short toms)			Nuclear (Gwe)			Other (quads)			Oil import		
Title	Year	Agency	1980	1985	1990	1980	1985	1990	1980	1985	1990	1980	1985	1990	1980	1985	1990	1980	1985	1990
U.S. Energy Through the Year 2000	1972	BOM	11.5	11.4		22.9	23.8		790	1,030		102	179		4.0	4.3		5.8	3.6	
U.S. Energy Outlook	1972	NPC (case I)	13.6	15.5		26.1	31.9		1,023	1,570		188	450		4.0	4.7		5.8	3.6	
		Case II	12.9	13.9		24.4	27.3		876	1,134		188	375		3.6	4.0		7.5	8.7	
		Case III	11.6	11.8		20.5	21.2		876	1,134		150	300		3.6	3.8		10.6	13.5	
		Case IV	8.9	10.4		17.3	15.0		830	1,004		107	240		3.3	3.6		16.4	19.2	
A Time To Choose	1974	Ford Foundation		14.2	[2] (17.0)		25.7	(31.0)		704	(968)		120	(168)		4.0	(15.0)		6.0	(6)
Project Independence	1974	FEA (BAU and AD) ($11 oil)	12.2– 13.5	14.7– 17.9	NA	20.7– 22.5	24.8– 15.0	NA		998– 1,085			190– 223			4.8		2.9– 4.6	0– 5.5	NA NA
U.S. Government Prospects	1974	National Association of Engineering		12.5			29.7			1,260			325			5.3			0	
Energy Self-Sufficiency: An Economic Evaluation [1]	1974	MIT: (1) Econometric Model ($11 oil)	14.7	NA		35.0			745			145			3.5			0		
		(2) Judgmental model ($11 oil)	13.6			23.8			745			145			3.5			0		
CTAB/Commerce	1975	Commerce Department		12.0			22.0			1,200			275			6.3			7.0	
U.S. Energy Through the Year 2000	1975	Bureau of Mines	11.9	14.8	NA	19.0	18.7	NA	806	998	NA	68	180	NA	3.8	3.9	NA	8.4	8.1	NA
		($8 oil)	11.9	11.4	8.8	20.2	20.4	19.1	787	894	1,041	55	120	193	3.7	3.9	4.2	7.6	13.5	20.7
National Energy Outlook	1976	FEA (ref. case $8 oil)	12.7	13.8	13.8	20.6	22.3	22.0	799	1,039	1,307	58	132	203	3.9	3.9	4.2	4.4	5.9	9.7
Towards Project Interdependence.	1975	CRS	11.0	12.0	NA	17.0	19.0	NA	800	900	NA	87	188	NA	4.2	5.9	NA	10.0– 10.6	9.0– 10.4	NA
An Assessment of U.S. Foreign Policy.	1976	Walter Levy	11.5	12.4	NA	18.6	19.2	NA	890	1,050	NA	58	132	NA	3.5	3.8	NA	9.2	10.7	NA
World Energy Outlook	1977	OECD	10.8	11.6	NA	17.5	20.9	NA	799	1,039	NA	68	152	NA	3.7	4.0			12.4– 14.6	NA
U.S. Energy Outlook	1977	CIA	10.0	10.0– 11.0	NA	18.7– 19.9	17.6– 19.7	NA	880– 950	980– 1,118	NA	51– 58	80– 123	NA	3.6	4.2	NA	10.5	12.0– 15.0	NA
National Energy Plan	1977	Executive Office of the President.		10.6			18.3			1,350			123			3.6			7.9	
	1976	Shell	10.4	10.9	12.1	17.6	16.8	14.3	736	969	1,257	64	187	355	3.0	3.0	3.2	10.0	10.7	10.2
	1978	do	9.5	9.4	10.1	16.6	14.7	12.7	800	997	1,340	64	116	171	3.0	3.0	3.2	10.0	11.3	11.3
	1978	Exxon	9.9	10.6	11.7	15.6	15.4	15.0	814	1,080	1,472	74	142	210						
	1977	do																		
Energy Supply and Demand	1978	EIA/DOE (med.)		10.8	10.4		16.7	16.2		1,034	1,257		94	158		4.2	5.0		11.0	13.8
Do	1978	Frankel	10.5	11.5	12.0	17.4	18.5	17.4	790	1,020	1,300	65	113	209	3.4	4.0	4.0	10.3	10.1	9.6
Do	1978	SRI	10.3	10.7	10.9	20.5	22.1	22.5	760	966	1,220	60	110	154	3.7	4.0	4.2	6.9	6.7	6.5
Project Interdependence	1978	CRS	10.0	10.9	11.4	17.4	16.9	16.9	775	940	1,225	81	131	175	3.2	4.0	5.0	10.0	11.8	12.9
Outlook for Oil in the 21st Century.	1978	Lichtblau	9.7	10.3	10.4	17.2	16.5	16.1	840	1,050	1,260	60	116	185	3.1	3.3	3.4	9.7– 10.3	9.4– 10.4	10.0– 11.7
U.S. Energy Demand and Supply 1976–85 (planning case).	1978	CRS/Franssen		9.5			16.9			940			113			4.0			12.7	

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[1] Energy demand econometric model: 46,000,000 (barrels per day) oil equivalent in 1980. Energy demand judgment model: 39,400,000 (barrels per day) oil equivalent in 1980. No data available for 1985 and 1990.

[3] Data in brackets are for the year 2000.

FIGURE 1.—U.S. Energy Demand Projections for 1980–1990: Various Forecasts Since 1974

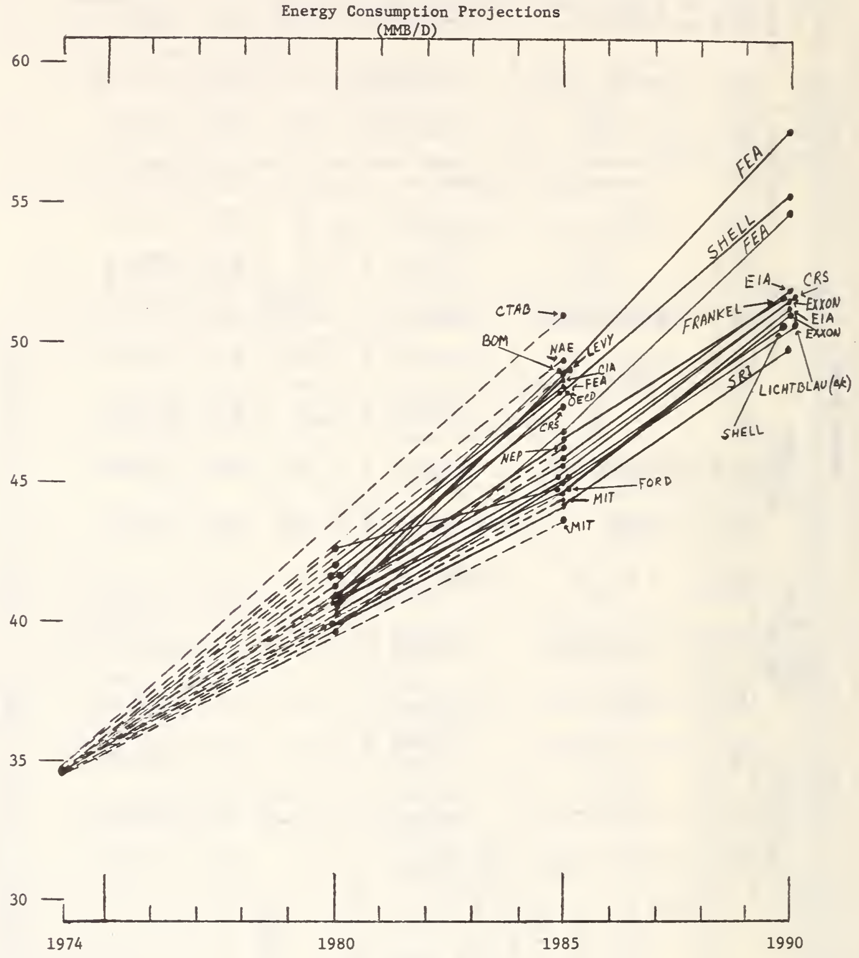


FIGURE 2.—U.S. Energy Supply Projections for 1980–1990: Various Forecasts Since 1973

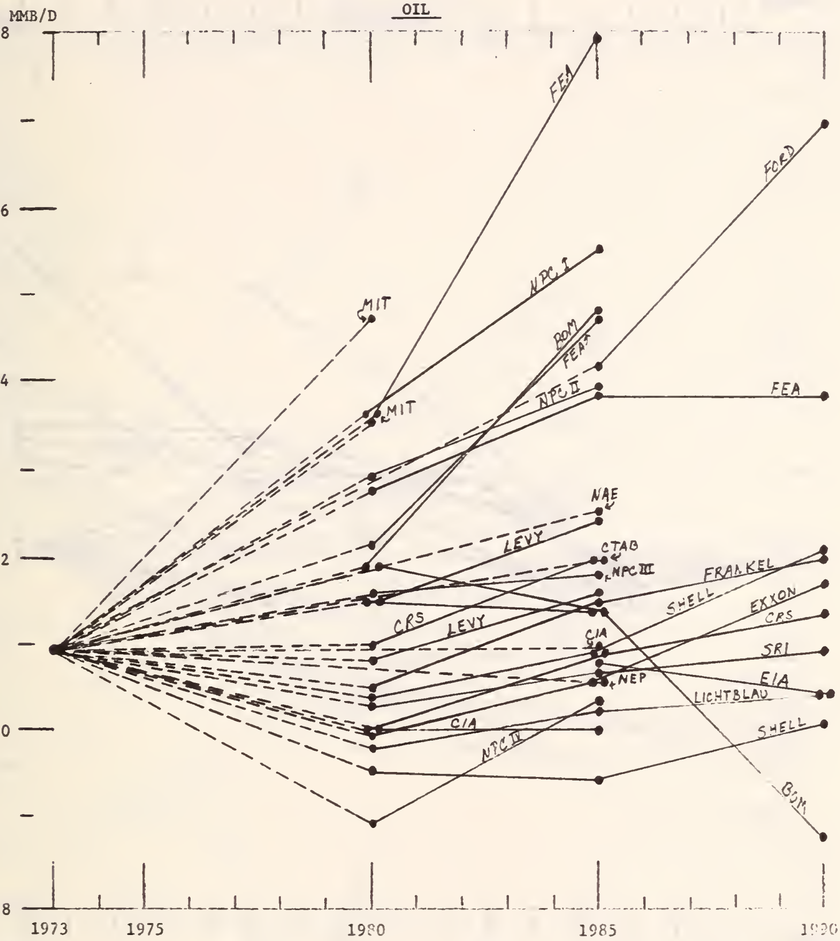


FIGURE 3.—Liquid Petroleum Production Projections of 12 Major Oil Companies: 1975–1990

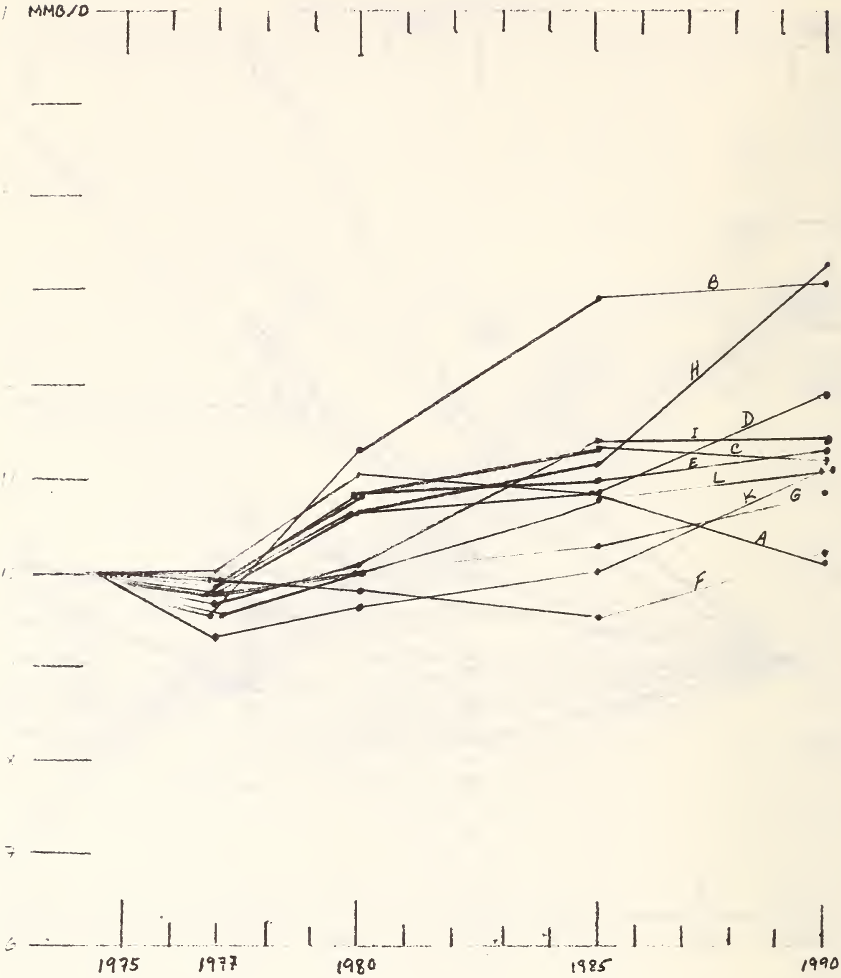


FIGURE 4.—U.S. Energy Supply Projections for 1980–1990: Various Forecasts Since 1973

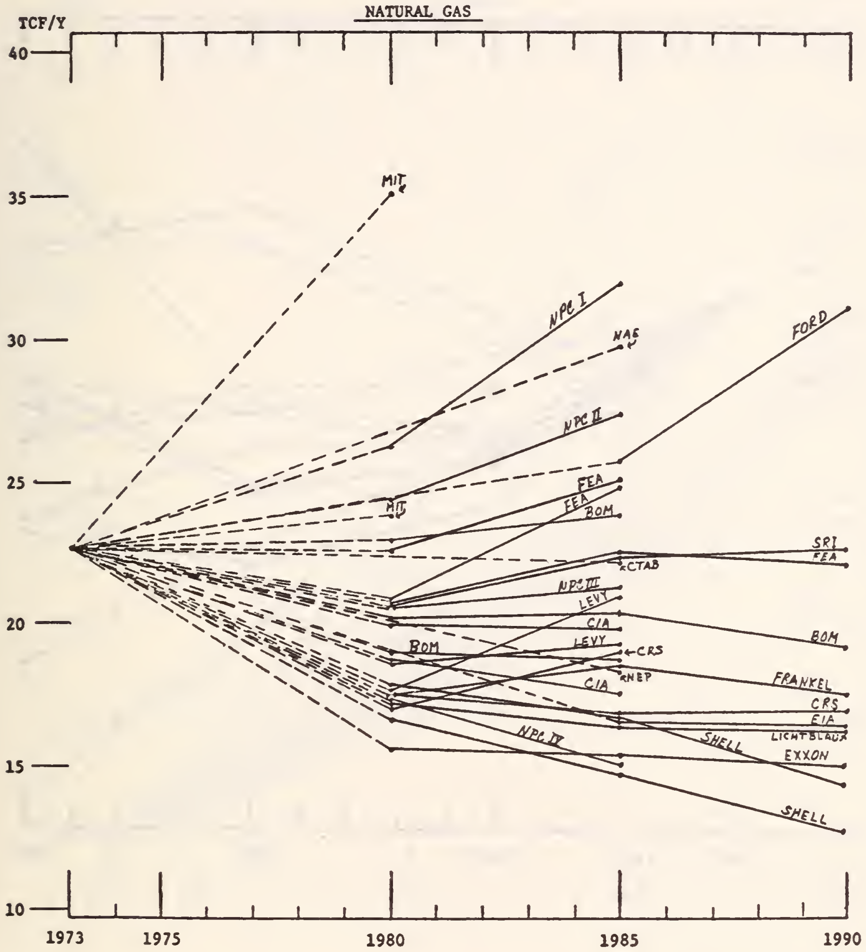


FIGURE 5.—Natural Gas Production Projections of 12 Major Natural Gas Producing Companies and the American Gas Association (Dry Gas) 1975–1990

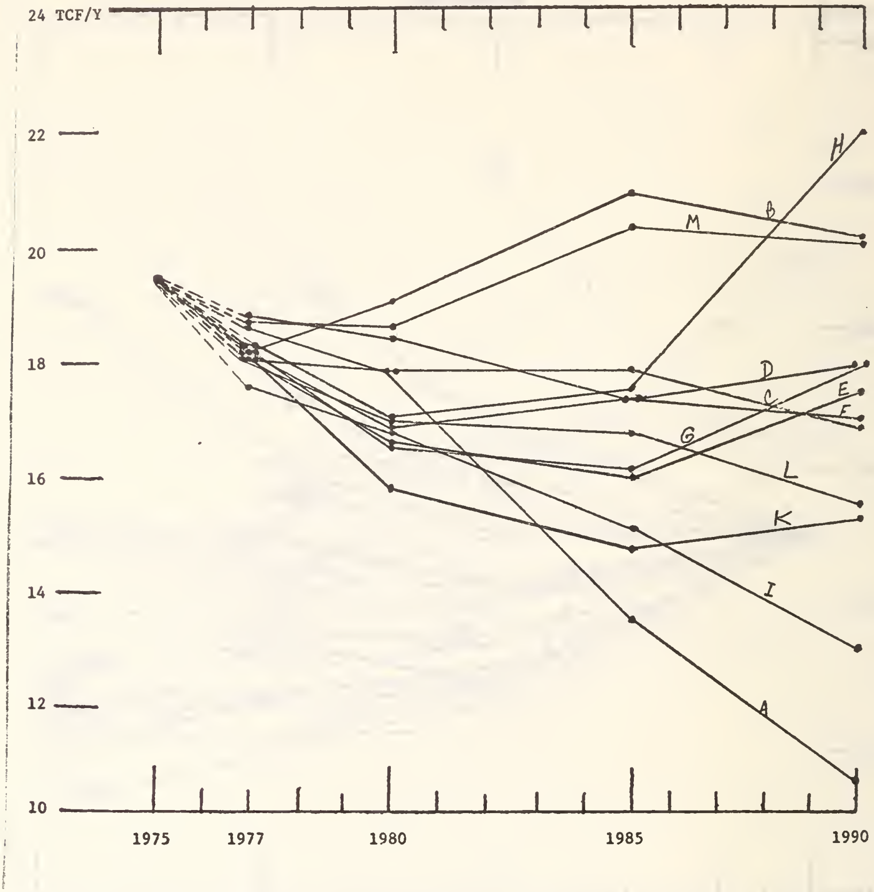


FIGURE 6.—U.S. Energy Supply Projections for 1980–1990: Various Forecasts Since 1973

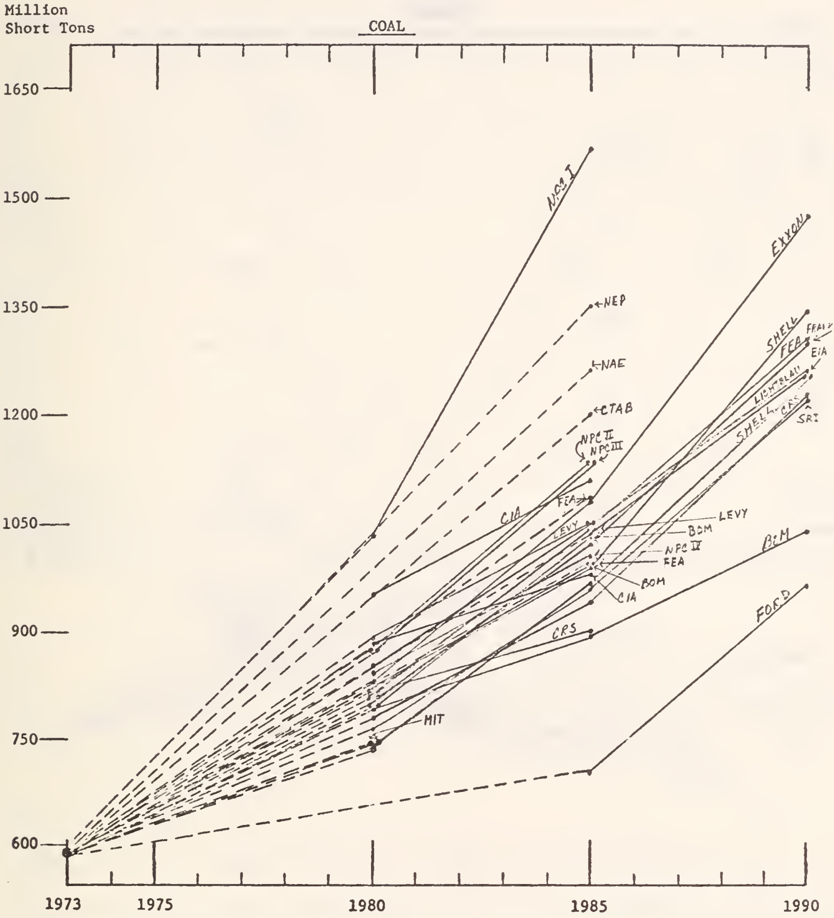


FIGURE 7.—U.S. Energy Supply Projections for 1980–1990: Various Forecasts Since 1973

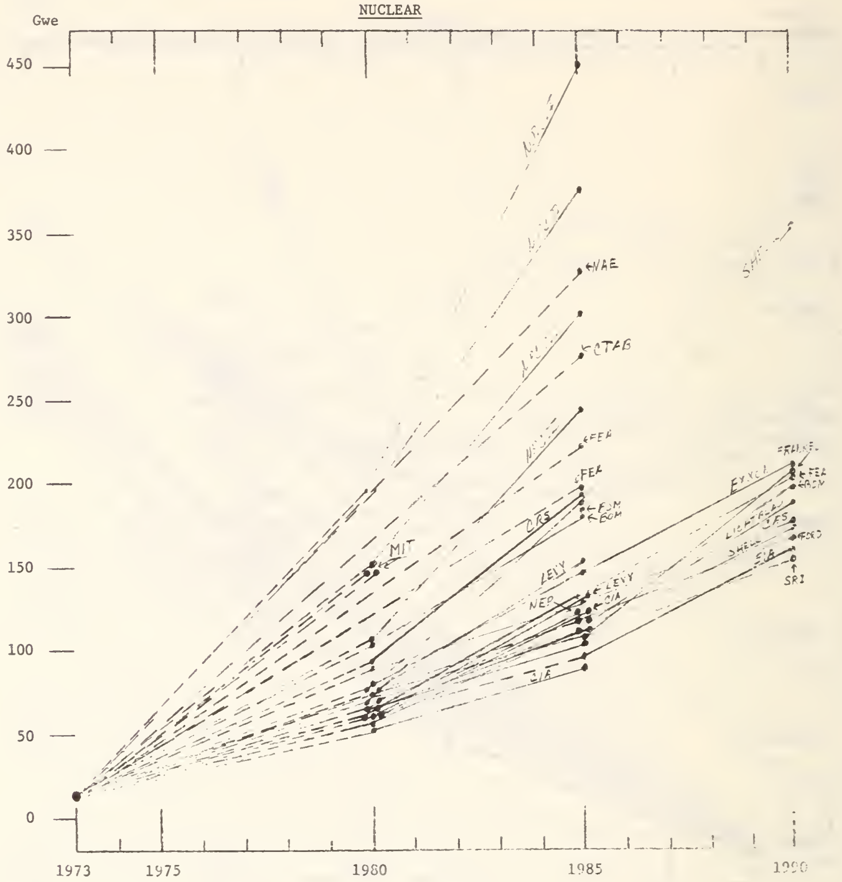


FIGURE 8.—U.S. Energy Supply Projections for 1980–1990: Various Forecasts Since 1973

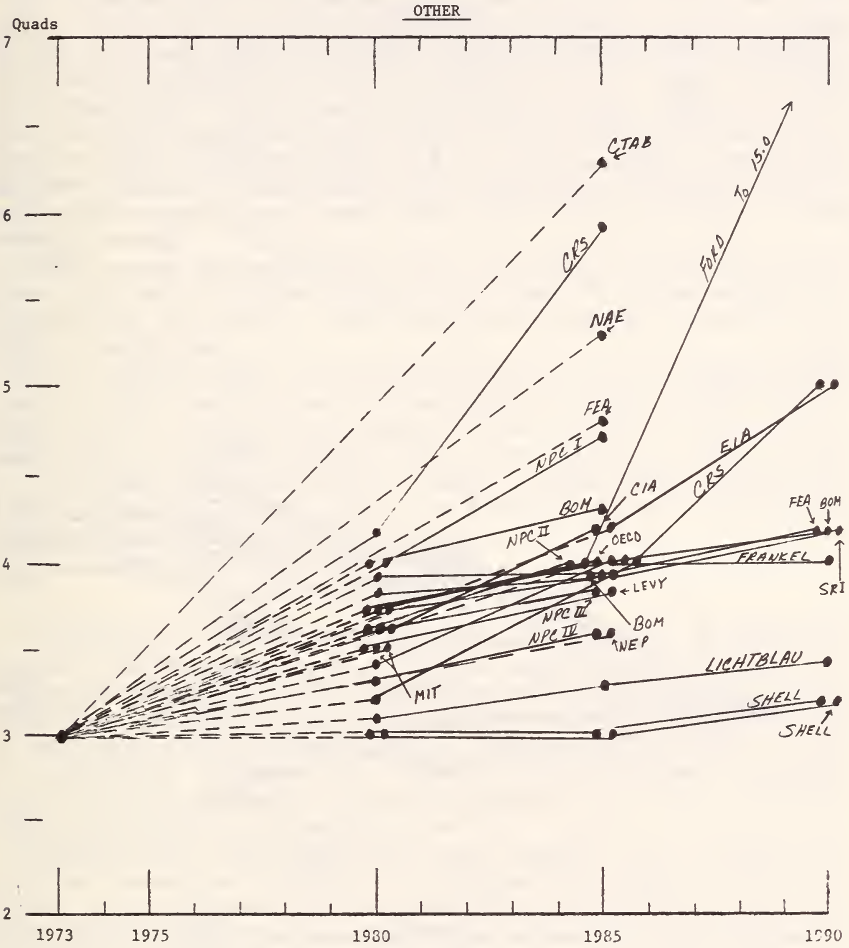
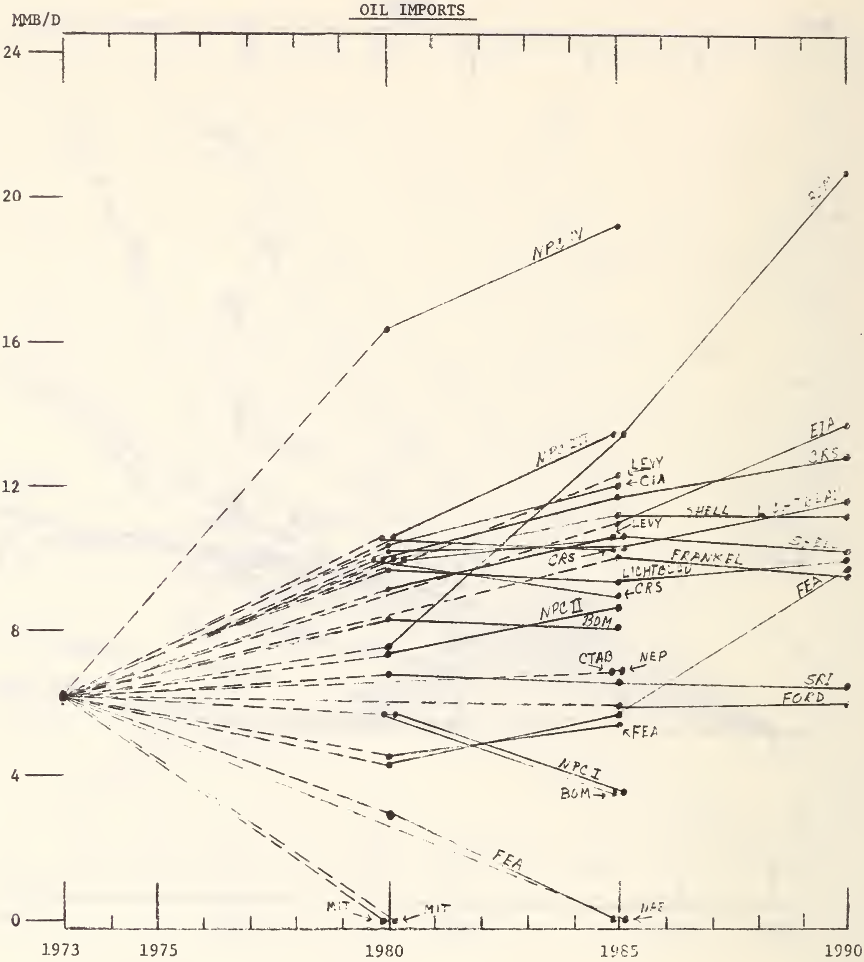


FIGURE 9.—U.S. Energy Supply Projections for 1980–1990: Various Forecasts Since 1973



Due to revisions of economic growth forecasts and energy demand elasticity, U.S. energy demand projections for the middle 1980's and 1990 have generally been revised downward between 1974 and 1978. The most recent 1978 DOE/EIA base case forecast of U.S. primary energy demand projects a total demand of 44.7 million bbl/d oil equivalent for 1985 and 51.3 million bbl/d oil equivalent for 1990. In 1974, DOE's predecessor, the Federal Energy Administration, projected U.S. energy demand at 46.7 to 48.8 million bbl/d oil equivalent for 1985 and between 54.8 and 57.5 million bbl/d oil equivalent for 1990. Studies by Shell, Exxon, the Congressional Research Service and other organizations show similar downward revisions of U.S. energy demand.

While energy demand in all of the 21 studies on table 3 range between 43.5 and 51 million bbl/d oil equivalent, the most recent 1978 studies have narrowed the range to between about 45.0 and 46.5 million bbl/d oil equivalent.

Most of the 1978 U.S. energy demand studies project average annual energy growth rates of between 2.5 and 3 percent through 1985. Underlying economic growth rates range between 2.9 and 4.1 percent per year with a multiplier ranging from a low of 0.7 to a high of 0.9.

Along with reductions in U.S. energy demand forecasts since the early and middle seventies, there has been a noticeable reduction in supply projections as well.

OIL AND NATURAL GAS LIQUIDS

Projections of U.S. oil and gas production made prior to 1975 were generally based on optimistic resource assessments by McKelvey of the U.S. Geological Survey and similar optimistic industry sources. These assumptions, combined with optimistic assessments of the effects of additional drilling on finding rates, resulted in the inflated oil and gas production projections in studies by the National Petroleum Council (1972), the Federal Energy Administration (1974), and other public and private organizations.

Following the publication of a most detailed U.S. hydrocarbon resources assessment tied to a statistical probability analysis of finding rates, the new reduced USGS resource estimates had the effect of lowering oil and gas production estimates for the decade of the 1980's in almost all post-1975 studies.

Table 4 and figure 2 show an oil production range for 1985 from 9.5 million bbl/d (CRS, 1978) to 17.9 million bbl/d (FEA, accelerated case 1974). The band had been narrowed down considerably by 1978 to between a low of 9.5 million bbl/d (CRS) and 11.5 million bbl/d (Petroleum Economics Ltd.). Most 1978 U.S. oil production projections for 1985 are between 10 and 10.5 million bbl/d. In all cases natural gas liquids have been added to crude oil in the forecasts.

Figures 3 is particularly interesting. It is based on a 1977 CRS study of the United States and world energy outlook (Project Interdependence). The author of the oil chapter sent questionnaires to the 15 largest oil companies in the United States and asked for their best supply estimates for 1980, 1985, and 1990 under the following assumptions:

(1) Decontrol of the price of all domestic oil after May 1979 and no windfall profit taxes added;

(2) Decontrol of new natural gas;

(3) Existing (1977) OCS leasing system;

(4) Annual average of 1.5 to 2 million acres of OCS lands leased by the Federal Government;

(5) No vertical divestiture;

(6) Naval Petroleum Reserve No. 4 in Alaska to be leased by the Department of the interior on terms similar to OCS leasing.

On the basis of the CRS assumptions and their own assumptions on reserves, resources, leadtimes, drilling and finding rates, 12 companies responded to the questionnaire in the following way:

TABLE 5.—LIQUID PETROLEUM PRODUCTION PROJECTIONS OF 12 MAJOR OIL COMPANIES, 1975–90

[In millions of barrels per day]

	1975	1977	1980	1985	1990
Company:					
A	10.0	10.0	11.1	10.8	10.1
B	10.0	9.5	11.3	12.9	13.0
C	10.0	9.8	10.9	11.4	11.3
D	10.0	9.7	10.7	10.8	11.8
E	10.0	9.9	10.9	11.0	11.4
F	10.0	9.9	9.7	9.5	10.3
G	10.0	9.7	10.0	10.4	10.8
H	10.0	9.7	10.7	11.2	13.2
I	10.0	9.6	10.1	11.5	11.5
J[1]	(8.4)	(8.3)	(8.3)	(7.7)	
K	10.0	9.3	9.5	9.9	11.2
L	10.0	9.5	10.0	10.7	11.2
Average of 11 companies	10.0	9.6	10.4	10.9	11.4

[1] 1 company provided data on crude oil only. All others included natural gas liquids. The average figures do not include data from company J.

The above table and figure clearly show the wide band in oil company estimates of future oil production under a number of important similar assumptions. The difference between the high and low estimates for 1985 and 1990 are respectively 2.0 and 2.9 million b/d.

To understand the magnitude of these different projections, the 1985 difference between the highest and lowest estimates are close to current daily oil production in Kuwait, and the difference in the 1990 U.S. production estimates is equivalent to the current production of Libya and Algeria together.

The above clearly shows that there is still a significant degree of uncertainty associated with oil production projections. Recent disappointing drilling experiences in the Gulf of Mexico (Destin dome) and the Gulf of Alaska are likely to move the concensus estimate in the direction of the lower projections until large new discoveries in relatively accessible areas or a technological breakthrough warrant a more optimistic upward revision of U.S. oil production estimates.

NATURAL GAS

Natural gas production projections, prior to 1975, were generally based on very optimistic assessments of the nation's liquid hydrocarbon resource base by McKelvey and others. These optimistic assessments, coupled with equally optimistic assumptions of supply elasticity, resulted in what now appear very high natural gas supply projections.

While current (1978) estimates of natural gas supply in 1985 range between 14.7 trillion cubic feet (tcf) and 22.1 tcf per year, the band between low and high estimates of the forecasts in table 4 and figure 4 is even wider. The highest estimates were made in the period from 1972 to 1974, when the FEA, the National Academy of Engineering, the Ford Foundation, and the National Petroleum Council projected 1985 natural gas production possibilities at between 24.8 (FEA) and 31.9 (National Petroleum Council, Case I).

Natural gas production estimates were gradually changed following the reassessment of the resource base by the U.S. Geological Survey (Circular 725 in 1975).

Most 1978 projections of U.S. natural gas production range between 15 and 17 tcf for 1985, and between 13 and 17 tcf for 1990. None of the above estimates include synthetic gas.

The uncertainty of natural gas supply projections is clearly shown from the data on table 4 and figure 4.

However, the underlying assumptions on price and Government policy differ considerably in the above studies. The 1977 Project Interdependence study by CRS attempted to narrow the range of assumptions by asking oil and natural gas producing companies to provide CRS with their best production estimates for 1980, 1985, and 1990, under the following assumptions:

(1) Decontrol of new interstate natural gas to the world market price of oil (Btu equivalent).

(2) Existing (1977) OCS leasing system.

(3) Leasing of 1.5 to 2.0 million acres of OCS lands per year.

(4) No vertical divestiture.

(5) Leasing of Naval Petroleum Reserve No. 4 on terms similar to OCS leasing system.

(6) No limits on imported LNG.

On the basis of these assumptions and their own assumptions on reserves, resources, drilling, and finding rates, 12 companies responded to the questionnaire in the following way: (see also fig. 5.).

TABLE 6.—NATURAL GAS PRODUCTION PROJECTIONS OF 12 MAJOR NATURAL GAS PRODUCING COMPANIES AND THE AMERICAN GAS ASSOCIATION, 1975–90 (DRY GAS)

[In trillions of cubic feet]

	1975	1977	1980	1985	1990
Company:					
A	19.2	18.6	17.8	13.7	10.6
B	19.2	18.2	19.1	20.8	20.1
C	18.6	18.1	17.8	17.8	16.7
D	19.3	18.2	16.8	17.2	17.9
E	19.0	18.1	16.5	16.0	17.3
F	19.2	18.8	18.4	17.2	16.9
G	19.7	18.3	16.4	16.1	17.9
H	18.6	18.3	17.0	17.4	21.9
I	18.6	17.5	16.7	15.2	13.0
J	(1)	(1)	(1)	(1)	(1)
K	19.7	18.2	15.8	14.8	15.1
L	18.6	18.1	16.9	16.7	15.5
M	18.8	18.7	18.7	20.3	20.0
Average of 12 companies	19.0	18.2	17.4	16.9	16.9

[1] Not available.

The band is even wider than the ranges between high and low oil forecasts. The difference between the lowest and highest projections of dry natural gas was 7.1 tcf for 1985 and 11.3 tcf for 1990. Discounting the lowest and highest estimates, most company estimates were between 15 and 18 tcf for both 1985 and 1990. Current forecasts by both public and private organizations are not much different from the average 1977 company projections.

Even if one discounts projections made prior to 1975, the degree of uncertainty related to U.S. natural gas production possibilities is still very high. The House/Senate Conference Committee on the natural gas bill estimated in October 1978 that total U.S. natural gas production without the bill would reach 15.2 tcf in 1985 as opposed to 16.6 tcf with the bill. Both production estimates are again within the 15–18 tcf production range as estimated by the majority of the oil and gas producing companies responding to the 1977 CRS questionnaire.

COAL

Projections of U.S. coal production for domestic use and exports have undergone significant changes since the 1970's. (See Table 4 and figure 6.)

Coal consumption in the United States peaked at about 17 quads in 1944 and declined very rapidly in the 1950's and 1960's. In 1961, coal consumption reached an alltime low of 9.9 quads. Consumption rose a little in the 1960's in absolute terms, but continued to lose its share of the total energy market. Some improvement was noticeable in the early 1970's, but, even then, coal barely maintained its share of the market of about 20 percent.

While coal consumption in 1944 reached an alltime high of about 17 quads, oil and natural gas consumption at that time were only about 13.6 quads. In 1946, oil and gas consumption surpassed coal, and by 1960, coal consumption had been reduced to about 25 percent of total fossil fuel consumption.

It is understandable that coal consumption forecasts in the fifties, sixties, and early seventies reflected what was actually happening at the time. The economics of oil and gas, environmental considerations and the future of nuclear power, as perceived in the 1960's and early 1970's, all conspired against the coal option.

Following the 1973–74 quadrupling of the price of oil, the natural gas scarcity of the middle seventies, and the reevaluation of the nuclear option, coal became, once again, an acceptable future energy option. Reserves are huge by anyone's standards, and were never considered a serious constraint to production.

Focusing on post-1974 studies, one finds a generally more optimistic assessment of the coal option. Most studies project U.S. oil consumption to grow to between 850 and 1,150 million tons per year. The differences in the outlook reflect the following uncertainties about the future of coal use in the United States:

(1) Demand for electric power.

(2) The future of nuclear power generation.

(3) Environmental constraints, and, in particular, the potential incompatibility of Clean Air Act regulations and expanded coal use in many parts of the country.

(4) Degree of success of the coal conversion program.

(5) Potential transportation, equipment, and skilled manpower bottlenecks.

(6) Government regulations related to health and safety.

(7) Water use problems in the West.

(8) Institutional problems, in particular, in the West.

In contrast to conventional oil and natural gas, there are no reserve constraints. Adjusting coal reserves for differences in Btu content, recoverable coal reserves amount to at least 150 billion tons, which is equal to at least two centuries of consumption at current levels.

NUCLEAR POWER

Until the middle 1960's, most nuclear power projections for the 1980's were fairly modest by today's standards. In fact, in the early sixties there was still a tendency to downplay the contribution of nuclear power in the 1980's somewhat.

From the middle 1960's until the middle 1970's, nuclear power projections escalated rapidly. The Atomic Energy Commission, for example, projected in 1967 that the country might have a nuclear power capacity of 145 gigawatts by 1980. This compares with an actual capacity of 45 gigawatts by the end of 1977. Most estimates in the late sixties and early seventies projected nuclear power generation at close to 150 gigawatts for 1980; between 150 and 300 gigawatts for 1985; and up to 1,500 gigawatts by the end of the century.

Projections made during the past 5 years are generally more modest (see table 4 and fig. 7), and, in particular, studies made after 1975. In 1974 and 1975, FEA's Project Independence, the Department of Commerce, CRS, and the National Academy of Engineering still projected a U.S. nuclear power capacity of between about 200 and 300 gigawatts by 1985. A year later, however, most nuclear power forecasts dropped to less than 150 gigawatts for 1985, and the most recent projections for 1985 hover around 100 gigawatts.

Among the principal reasons for the sharp drop in nuclear power forecasts are:

(1) Lower estimates of base load requirements in the 1980's.

(2) Escalation of capital costs.

(3) The speed at which the Federal Government can license construction and operation of additional nuclear powerplants.

(4) Continued opposition to nuclear power by interest groups, notably those concerned with the environment.

(5) Opposition by State governments to nuclear powerplant siting and waste management.

HYDROPOWER, GEOTHERMAL, SOLAR, AND OTHER ALTERNATIVE ENERGY SOURCES

While renewable energy sources are much of the answer to our long-term energy and environmental problems, few studies have projected a very substantial increase from the above energy sources through 1990.

Most energy forecasts undertaken between 1974 and 1978 project a contribution of approximately 3 to 6 quads, or an oil equivalent of about 1.5 to 3 million barrels per day from all the above sources in the middle and late 1980's (see table 4 and fig. 8).

OIL IMPORTS

Oil and gas imports are generally treated as the residual between domestic demand and supply. Until recently, natural gas imports were expected to remain fairly steady at about 5 percent of total as consumption.

If the principal energy problem, as perceived by policymakers, is related to the volume and geographical distribution of U.S. oil imports, one must regret to say that energy forecasts tend to show that little progress has been made since the 1973 oil embargo.

With the exception of Government and other studies undertaken in the 1970's with the specific purpose to prove that the Nation could reduce its oil imports by the early or middle 1980's, few recent studies now claim that this can or will be accomplished.

Table 4 and figure 9 show clearly what happened to energy forecasts in the past 5 years. Reduced prospects for future economic growth and a high degree of optimism on energy conservation have caused a significant reduction in total primary energy demand forecasts. Unfortunately, energy forecasters have also become increasingly pessimistic about the various short- and medium-term domestic supply options.

Hence most recent projections of U.S. oil imports continue to hover between 10 and 13 million b/d for 1985, with little hope of significant improvement of the situation through 1990.

If these studies prove to be correct, the U.S. economy will face a period of growing dependence on the rest of the world. Some restructuring of our economy will be called for to meet this new challenge. In the past the U.S. economy was better sheltered against disruptions elsewhere in the world. Growing dependence on exports to pay for rising oil imports would lead to further interdependence of the world economy.

CONCLUSION

Energy forecasts undertaken in the United States in the middle 1960's and early 1970's reflected the optimism of future economic growth rates and paid relatively little attention to prices and supply constraints. Following the 1973–74 quadrupling of the world price of oil, optimistic assumptions on the future impact of conservation, coupled with lower projections of U.S. economic growth rates, resulted in generally lower energy demand projections for the 1980's and beyond. While there is a considerable degree of agreement on the above assumptions, energy forecasters disagree on the extent of the future demand reductions.

Along with lower demand forecasts in recent years, there has also been a marked decline in projections of domestic oil, natural gas, and nuclear power.

On balance, projections of U.S. oil imports have, therefore, not changed very much during the past 5 years.

CHAPTER III—FREE WORLD ENERGY OUTLOOK: A COMPARISON

In recent months a number of free world energy demand and supply analyses have been published. A careful examination of these studies shows that energy analysts are generally converging in their projections of total free world energy demand through 1985–90, non-OPEC oil supplies and nonoil energy supplies. Considerable differences of opinion remain in assessing energy demand and supply of the centrally planned economies and the most likely level of OPEC oil production.

Comparing the 1978 studies with similar efforts undertaken between 1974 and 1977 by the same or by other organizations, one finds a downward trend in both free world energy demand and supply projections (see tables 7–9 and figures 10–12). In the 16 studies in table 7, free world energy demand ranges from an oil equivalent of 102.6 MMB/D to 106.7 MMB/D in 1980 (about 5 percent difference); from 122.3 MMB/D to 131.2 MMB/D in 1985 (about 8 percent difference); and from 146.1 MMB/D to 156.6 MMB/D in 1990 (about 6 percent difference).

FIGURE 10.—U.S. Energy Demand Projections for 1980–1990: Various Forecasts Since 1974

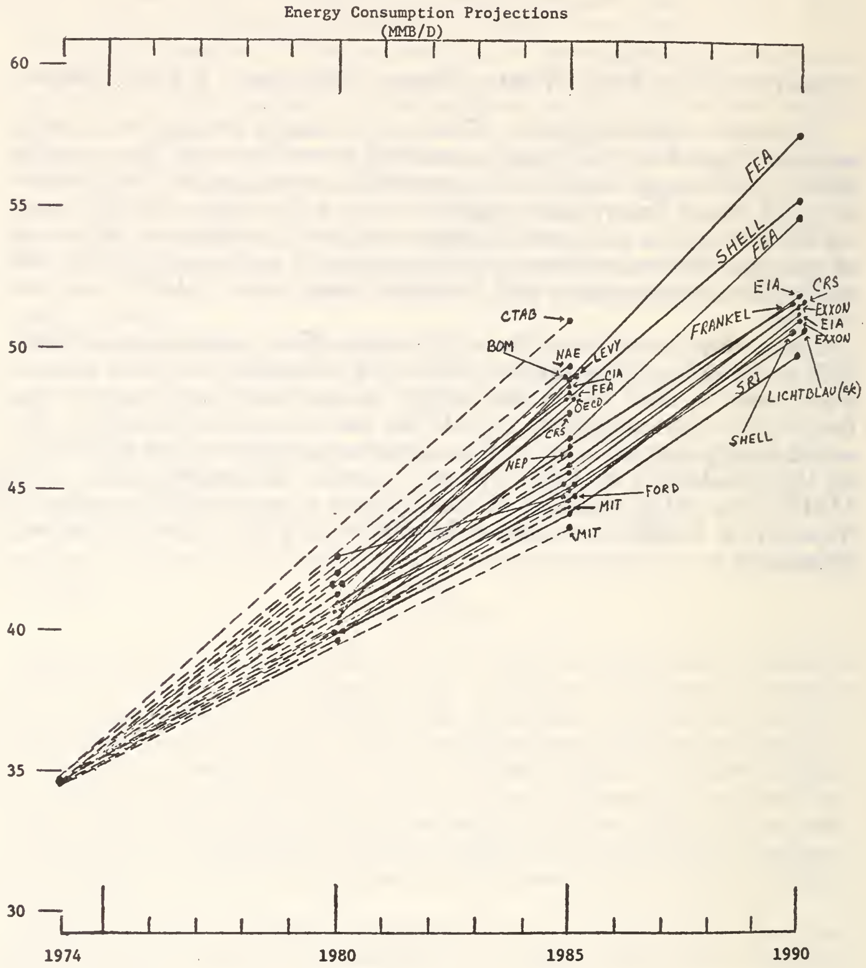


Figure 11.—Forecasts of OPEC Production Possibilities Undertaken: 1975–1978 (MMB/D)

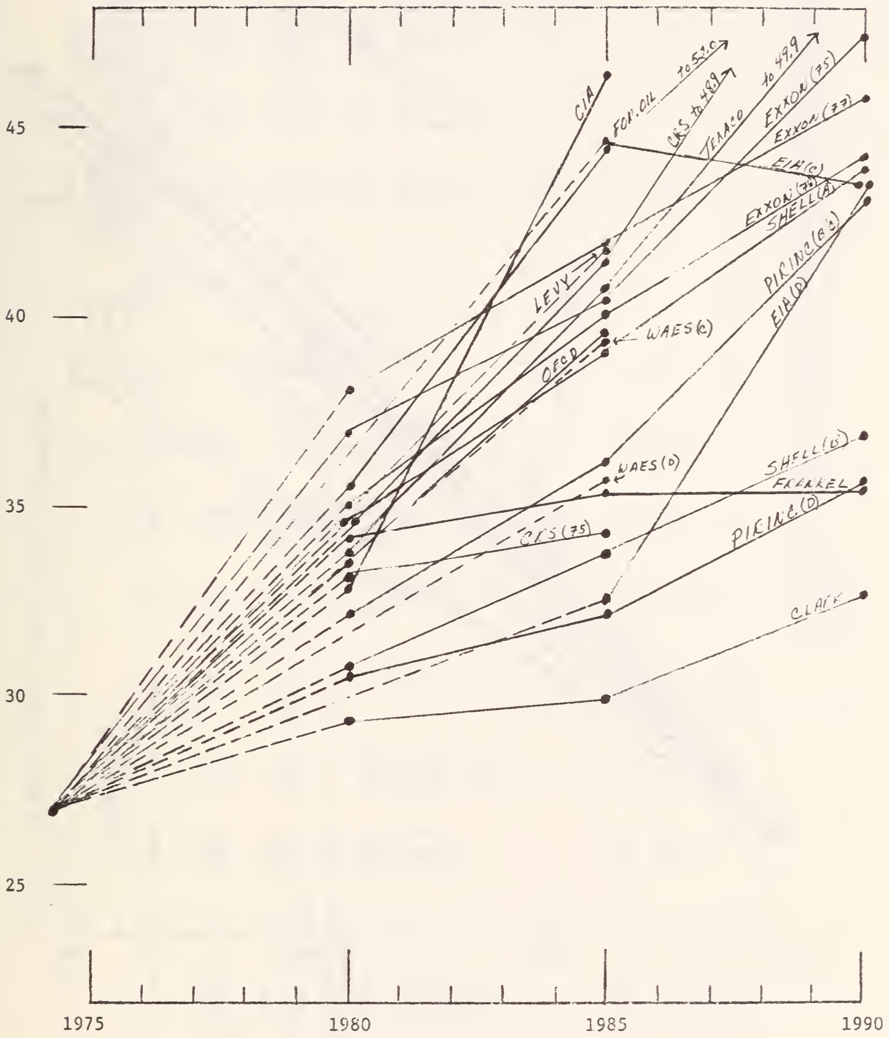


FIGURE 12.—Free World Oil Production Forecasts: 1975–1978
(MMB/D)

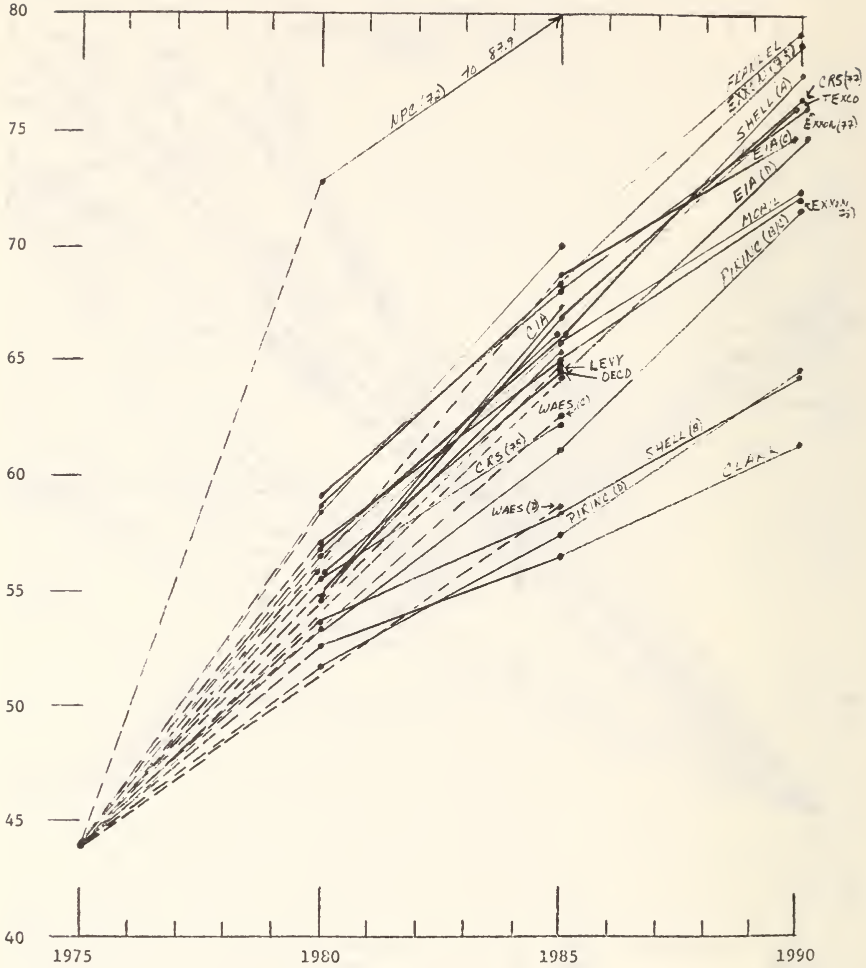


TABLE 7.—FREE WORLD ENERGY DEMAND FORECASTS THROUGH 1990

Title	Year issued	Organization	Energy demand (in million barrels per day)			Oil demand			OECD average annual energy demand growth		OECD average annual GNP growth		OECD E/GNP growth ratio	
			1980	1985	1990	1980	1985	1990	1975–80	1980–90	1975–80	1980–90	1975–80	1980–90
World Energy Outlook	[1] 1975	Exxon	108.0	131.2	159.3	58.5	67.2	78.7	3.8	3.3	4.0	3.9	0.95	0.85
Free World Energy and Petroleum Demand, 1976–90.	1976	Texaco	105.6	128.5	154.2	56.7	66.1	76.0	3.8	3.3	4.4	3.8	.86	.86
Scenarios for the Eighties—An Update:														
Case A (high economic growth)	1976	Shell	103.8	128.1	159.2	57.5	67.2	77.4	4.4	3.7	NA	4.5	NA	.82
Case B (low economic growth)			98.0	110.2	124.7	53.8	58.8	64.6	3.3	2.2	NA	2.7	NA	.81
Toward Project Interdependence	[1] 1975	CRS	107.2	128.5	153.8	55.5–58.4	62.1–68.2	NA	NA	NA	NA	NA	NA	NA
A World Energy Study—Vol. 5	1976	Sherman Clark Association.	103.9	118.9	134.7	55.1	59.1	63.9	3.3	2.2	4.7	4.1	.70	.54
U.S. Energy Outlook	1972	NPC	124.2–129.7	159.1–172.4	NA	69.1–77.9	83.9–103.4	NA	(1970–85 4.0–4.4)		NA	NA	NA	NA
An Assessment of U.S. Energy Policy	1976	Levy	NA	119.0	NA	NA	64.8	NA	NA	NA	NA	NA	NA	NA
World Energy Outlook	1977	Exxon	108.3	130.8	157.9	59	68	76	4.0	3.1	4.3	3.7	.9	.8
Do	1978	do	105.3	125.2	147.8	57	65	72	3.3	2.8	3.9	3.7	.85	.76
Do	1977	OECD	101.8	126.7		55.6	65.6	NA	3.6	3.4	4.3	4.1	.84	
WAES:														
(C)	1977	MIT		123.2			62.5		4.4		5.2		.6	
(D)	1977	MIT		114.0			58.4		3.2		3.4		.9	
Annual Report to Congress:														
(C)	1978	EIA		121.8	151.6		[2] [3] 60.4–66.0	[2] [3] 72.7–82.8	(1976–85 4.3)	(1986–90 4.5)				
(D)	1978	EIA		116.6	141.2		61.9	74.8	(1976–85 3.9)	(1986–90 3.9)				
Outlook for World Oil Into the 21st Century:														
(B/C)	1978	PIRINC	102.6	122.3	146.4	54.4	61.6	71.9	3.7		4.0 4.5		.85	.8
(D)			101.1	118.4	139.1	52.8	57.7	64.7	3.3		4.0		.75	.7
Technical Analysis of the International Oil Market.	1978	Frankel	120.4	120.3	139.3	56.1	61.5	64.4	3.0		NA		NA	
International Energy Prospects to 2000	1978	Foreign Oil Co.	106.7	131.2	156.5	58.0	69.1	79.0			4.8	4.3		
1979–90 METS Assumptions Summary of Key Findings.	1978	Mobil	NA	122.9	146.1	NA	64.3	74.0	(1977–85 4.0)	(1985–90 3.5)				

[1] December.
[2] Higher prices.
[3] Constant dollar 1978.

Note: 1965–73 economic growth rates in OECD averaged 4.7 percent and energy growth rates were 5.1 percent—E/GNP ratio was 1.1 for the OECD. Total free world energy consumption in 1975 was 79,800,000 barrels per day oil equivalent. Total free world oil consumption in 1975 was 44,100,000 barrels per day.

TABLE 8.—FREE WORLD FORECASTS OF NONOIL SUPPLY

[In millions of barrels per day oil equivalent]

Title	Year issued	Organization	Natural gas 1980	Natural gas 1985	Natural gas 1990	Coal 1980	Coal 1985	Coal 1990	Nuclear 1980	Nuclear 1985	Nuclear 1990	Other 1980	Other 1985	Other 1990
World Energy Outlook	[1] 1975	Exxon	17.8	20.4	22.2	19.0	22.6	26.2	4.9	11.0	19.7	7.5	9.1	10.6
Free World Energy and Petroleum Demand 1976–90.	1976	Texaco	19.6	23.0	27.0	20.3	23.6	27.4	3.8	9.0	15.9	6.0	6.9	7.9
Scenarios for the Eighties—An Update:														
Case A (high economic growth)	1976	Shell	18.0	20.4	23.1	17.0	20.9	26.4	4.8	11.6	21.8	6.5	7.6	9.5
Case B (low economic growth)			17.2	18.4	18.8	16.1	17.2	18.3	4.6	8.9	15.6	6.3	6.8	7.0
World Energy Outlook	1977	Exxon	17.5	20.4	23.1	19.6	23.8	29.3	4.5	9.8	17.4	7.3	9.1	11.7
Do	1978	do	17.2	19.2	21.6	19.6	24.0	29.7	3.9	7.6	12.5	20.0	25.1	32.0
WAES:														
C	1977	MIT		22.1			21.6			12.0			8.4	
D	1977	MIT		19.7			18.8			10.1			7.7	
International Energy Prospects to 2000	1978	Foreign Oil Co	17.2	20.2	23.3	20.2	22.4	26.3	4.1	8.0	13.0	7.1	8.3	9.9
Outlook for World Oil in the 21st Century	1978	PIRINC	17.6	21.0	24.4	19.6	22.6	25.8	4.0	8.1	13.6	6.6	7.8	9.1
Technical Analysis of the International Oil Market.	1978	Frankel	17.6	21.4	24.9	17.8	21.0	25.1	4.2	7.5	13.6	6.7	8.9	11.3

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[1] December.

TABLE 9.—FREE WORLD OIL PRODUCTION FORECASTS

Title	Year Issued	Organization	Production	Projections (total)			OPEC (million barrels per day)		
				1980	1985	1990	1980	1985	1990
World Ene·y Outlook	[1] 1975	Exxon	43.8	58.5	68.2	78.7	36.7	40.5	47.8
Free World Energy and Petroleum Demand, 1976–90	1976	Texaco	43.8	56.7	66.1	76.0	33.8	40.9	49.9
Senarios for the Eighties—An Update:									
Case A (high economic growth)	1976	Shell	43.8	56.9	66.1	77.4	34.6	38.8	43.9
Case B (Low economic growth)			43.8	53.2	58.3	64.1	30.9	33.8	36.9
Toward Project Interdependence	[1] 1975	CRS	43.8	55.5–58.4	62.1–68.2	NA	33.0–35.9	34.1–40.2	NA
A World Energy Study—Vol. II	1976	Sherman Clark Association.	43.8	52.5	56.3	61.2	29.4	29.9	32.8
U.S. Energy Outlook	1972	NPC	(1971:41.6)	[2] 72.8	[2] 87.9	NA	NA	NA	NA
An Assessment of U.S. Energy Policy	1976	Levy	43.8	NA	64.8	NA	NA	41.9	NA
World Energy Outlook	1977	Exxon	43.8	59.0	68.0	76.0	38.0	42.0	46.0
Do	1978	do	43.8	57.0	65.0	72.0	35.0	40.0	44.0
Do	1977	OECD	43.8	55.6	64.6	NA	33.5	39.3	NA
Project Interdependence	1977	CRS	43.8	54.8	66.9	76.3	34.6	42.8	48.9
WAES:									
(C)	1977	MIT			62.5			39.0	
(D)	1977	MIT			58.4			36.0	
The International Energy Situation	1977	CIA		54.9–56.7	67.1–73.6	NA	39.9–34.7	46.7–51.2	[3] NA
Annual Report to Congress:									
(C)	1978	EIA			68.5	74.8		[4] 44.5	43.5
(D)					64.4	74.8		33.1	43.5
Outlook for World Oil Into the 21st Century:									
B/C	1978	PIRINC		53.1	61.0	71.5	32.2	36.6	43.1
D				51.6	57.2	64.2	30.7	32.8	35.8
Technical Analysis of the International Oil Market	1978	Frankel		55.1	61.0	64.4	34.0	35 5	35.5
International Energy Prospects to 2000	1978	Foreign Oil Co		58.2	70.0	79.0	35.8	44.6	[3] 52.0
1979/90 METS Assumptions Summary of Findings	1978	Mobile		55.6	65.3	72.1	NA	NA	NA

[1] December.

[2] Available free world supply to meet base case demand.

[3] Needed from OPEC.

[4] Maximum OPEC capacity for 1985 set at 38.5 by DOE. EIA projects OPEC production of 44,500,000 barrels per day.

These differences in free world demand estimates are not very large given the uncertainties about economic growth rates, demand elasticities, and prices. In case all of the 1978 studies were adjusted for differences in projected economic growth rates above, differences in total projected free world demand would at least be halved.

The free world energy demand outlook has been reduced in recent years for two principal reasons; expectations of future OECD economic growth rates have declined, and, energy conservation in the OECD has been so encouraging in the past 3 years that many energy analysts are now more confident about the ability of the industrial nations to reduce energy consumption substantially in the next decade. Finally, the most recent studies—1978—reflect the use of a later base year from which future energy demand is calculated. The disappointing performance of the world economy in recent years was not foreseen in the earlier studies, and subsequently the 1978 studies, using a later base year, reflect the lower energy demand of recent years.

In the same period between 1974 and 1978, free world energy supply estimates have also undergone significant change. The early optimism of the future contribution of nuclear power has been shattered by recent developments in most OECD member countries. Oil and natural gas production projections for the United States, Canada, and the North Sea countries, have been substantially reduced during the past 5 years; and, the prospects for rapidly increasing coal use in the United States have been downplayed in the most recent studies.

Comparing a number of the 1978 free world energy demand and supply studies, one finds that while non-OPEC energy supply as well as free world energy demand estimates have narrowed substantially, there is no more agreement now on future OPEC available supply and on CPE energy developments, than there was a few years ago. The CIA thesis on potential CPE imports has been dismissed by most non-Government energy forecasters, but careful examination shows that rejection of the CIA thesis is mainly based on intuition rather than intensive analysis.

Significant differences on future OPEC production and CPE import (or exports) are sufficient to classify authors of energy studies in the "optimistic" or "pessimistic" camp. High CPE imports combined with low OPEC production should reduce the current world oil surplus before the middle 1980's, even if economic growth rates in the OECD continue to be below current official projections.

Energy "optimists" foresee lower free world economic growth rates in the future and they are frequently more optimistic about energy demand elasticity as well. "Pessimists" argue that currently projected OECD long-term economic growth rates are reasonable, and that such growth rates coupled with some improvement in energy conservation could result in tighter oil supplies even before the middle 1980's and in the absence of any CPE oil imports. Lower economic growth rates, they argue, would result in higher rates of unemployment and a growing threat of protectionism in Europe and the United States. Policymakers are expected to succeed in using available tools to prevent further deterioration of the economics of the industrial world.

Energy "optimists" tend to study recent improvements in energy conservation in the OECD countries and conclude that the energy/GNP ratio can be reduced substantially in the future. "Pessimists" do not entirely agree with the interpretation of OECD energy demand data from recent years, and they argue that it is too early to assume that further dramatic improvements in the energy/GNP ratio will be forthcoming in the future, All agree on improved prospects for conservation because of higher prices and Government policy, but they differ on the degree of energy savings in the various OECD regions over time.

"Optimists" and "pessimists" do not all fall neatly in one of the above categories, A study may project low energy demand, coupled with low free-world supply and high CPE imports. This combination is likely to put the study in the "pessimist" group. Another study may project high energy demand, coupled with high OPEC and non-OPEC supply and little—if any—CPE imports. Such a study would probably end up on the "optimist" camp.

The degree of optimism or pessimism is usually reflected in the degree and timing of oil supply tightening. In this respect the reader should be reminded of the fact that the current OPEC surplus capacity is only 6 MMB/D and the available surplus only 3 MMB/D. Half a percentage point more or less economic growth in the free world could result in 13 MMB/D oil equivalent more or less energy demand, and optimistic or pessimistic expectations on conservation in the free world could add to or reduce energy consumption by several MMB/D oil equivalent in the next decade.

The differences between the optimists and pessimists on either economic growth rates or demand elasticities are sufficient to absorb the entire OPEC surplus capacity in about half a decade.

RECENT STUDIES

Of the 16 studies in table 7, the following recently published surveys will be analyzed in more detail below:

1. Exxon Corporation, World Energy Outlook.
2. Energy Information Agency (DOE), Projections of Energy Supply and Demand and Their Impacts.
3. Petroleum Economists Ltd., Technical Analysis of the International Oil Market (PIRINC).
4. Petroleum Industry Research Foundation, The Outlook for World Oil into the 21st Century.
5. Petrocan/Petroven, International Energy Prospects to 2000.
6. Congressional Research Service, Project Interdependence, U.S. and World Energy Outlook Through 1990.
7. International Energy Agency, Reviews of National Energy Programs.

DIFFERENCES IN VIEW

While it is clear that for a given rate of economic growth there are remarkable similarities in the forecasts of energy demand, the optimists see slower economic growth preventing supply tightening and the pessimists argue that tight oil supply may significantly reduce economic growth rates.

Extrapolating recent experiences in energy conservation, the optimists assume higher demand elasticities than the pessimists.

CONCLUSIONS

Exxon

Projects a possibility of some tightening of supply of oil in the long run. While the transition to a new energy era will call for some difficult policy decisions, the world economy is already adjusting to changes in the energy environment. If the necessary decisions are made, there is no reason to conclude that the changing energy market will necessarily be a serious constraint on world economic growth for the rest of the century.

EIA/DOE

EIA assumes higher economic growth rates than Exxon—base case OECD projections. Given these growth rates; current views on energy conservation; differing oil production levels and prices, there may be considerable market pressure on OPEC production capacity and on world oil prices in the 1980–90 time frame.

Petroleum Economics Ltd. (Frankel)

The study points out that although oil has historically been the swing fuel providing the margin for meeting peak demand when other fuels were fully committed, this role may be limited in the future thus compounding the overall energy problem for the industrial nations. Conservation is required to reduce energy demand growth rates. The study suggests that implementation of an effective conservation policy in the industrial countries will ease supply options.

Increasingly tighter oil supplies are projected for much of the 1980's with subsequent international economic and financial uncertainty.

PIRINC

The study concludes that an oil shortage before the late 1980's is unlikely, that an oil shortage thereafter is a possibility but not a probability and that gradual transition from oil to other energy sources accompanied by moderate real price increase over the next quarter of a century, is more likely than an oil crisis.

Petrocan/Petroven

Energy demand is supply constrained. Energy growth rates can rise unconstrained at 4.4 percent per year until 1985, but thereafter at a supply-constrained rate of only 2.5 percent p.a. to reach 190 MMB/D by 2000—93 MMB/D in 1977 and 130 MMB/D in 1985. Hence, economic growth may be limited by energy supply.

Oil supply constraints could appear as early as 1982–85 but no later than the early 1990's. After 1985, there are likely to be significant oil import constraints on the developed countries. This would lead to upward pressures on prices.

Congressional Research Service

There will be sufficient free world productive capacity to meet world oil demand at medium economic growth rates throughout the 1980's, provided the Soviet bloc does not become a major importer of oil. Sometime between the late 1980's and middle 1990's productive capacity of free world oil is likely to peak followed by declining world production. There is no guarantee that surplus producers will increase production to meet free world demand. For political and economic reasons world oil demand could outpace supply as early as the early 1980's or as late as the middle 1990's. This would result in higher prices.

International Energy Agency (IEA)

The IEA analysis, based on the demand and supply inputs of each of the member countries has found that there is a strong probability of a significant imbalance between the potential demand for free world oil and the level of supply likely to be available from OPEC.

The result of the potential imbalance between demand and supply would lead to a strong upward pressure on prices. This could happen even before 1985, in anticipation of tight market conditions.

There are, however, many similarities in the approach of these studies. They all calculate total demand for energy in the free world, and the contribution nonoil energy sources and indigenous oil will make to meet demand. All essentially treat OPEC oil as the world's swing fuel, meeting all demands that are otherwise not met. OPEC is treated as the residual supplier to both the industrial countries and the centrally planned economies (CPE's).

ENERGY DEMAND PROJECTIONS

Aggregate energy demand is a function of economic growth rates and demand elasticity. The forecasts of energy demand in 1985 and 1990 from the seven studies are given in table 10.

TABLE 10.—ENERGY DEMAND IN 1985 AND 1990

[Million barrels per day oil equivalent]

	United States		Canada		OECD Europe		Japan		Other		Total free world	
	1985	1990	1985	1990	1985	1990	1985	1990	1985	1990	1985	1990
Exxon	45.0	51.0	(1)	(1)	33.0	39.0	12.0	13.0	35.0	45.0	125.0	148.0
EIA/DOE (medium case)	45.2	51.9	5.7	6.7	31.4	39.0	11.4	15.7	29.0	39.5	122.8	152.8
Petroleum economics	46.5	51.5	5.4	6.1	31.0	35.0	11.0	13.0	26.4	33.7	120.3	139.3
PIRINC (medium case)	45.0	50.6	(1)	(1)	31.9	36.9	11.1	14.0	34.3	44.9	122.3	146.4
Petrocan (medium case)	50.4	57.7	5.5	6.4	36.0	41.5	11.5	14.2	27.7	35.6	131.2	154.9
Congressional Research Service	45.1	51.5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
IEA	46.9	52.7	5.5	6.6	31.2	[2] 33.8	11.9	14.3	[3] 22.4	31.7	[4] 118.0	[4] 139.1

[1] Included in "Other".

[2] Adjusted with SRI projection for France, which is not an IEA member.

[3] LDC's only.

[4] Does not include Oceania, South Africa, and Israel.

NA=Not available.

Table 10 indicates very close agreement between the demand base cases of most of the seven studies. From the available information it would appear that only the Petrocan study's demand outlook differs from the others, but by no more than about 5 to 6 percent. The difference between the high and low demand estimates in the seven studies is no larger than 2 to 3 percent by the middle 1980's.

Of the various regions in table 10, the demand forecasts differ most for the "other" group, which is primarily represented by the developing countries. In view of the fact of our very limited knowledge of economic growth potential and demand elasticities in this huge and diverse group of countries, it seems reasonable that projections differ most for this group. The two highest estimates, PIRINC and Exxon, include Canada in the "other" group.

The most important assumptions underlying energy demand forecasts are economic growth rates and demand elasticities. For the economy as a whole, the latter is generally calculated by dividing GNP growth rates by total primary energy growth rates. Projections of economic growth rates and demand elasticity are generally available for the industrial countries, but are frequently lacking for the developing countries. The available growth rates and energy growth coefficient are shown in table 11.

TABLE 11.—INDUSTRIAL COUNTRIES ECONOMIC GROWTH RATES TO 1985–90. AVERAGE ENERGY DEMAND/GNP GROWTH RATIOS FOR THE OECD AREA, AND AVERAGE ENERGY GROWTH RATES

Base cases only]

	Economic growth rate (percent per year)	Energy demand growth rate divided by GNP growth rate	Energy demand growth rate (percent per year)
Exxon	3.8	.80	3.0
EIA/DOE	4.1	.89	3.6
Petroleum Economics	NA	NA	3.0
Pirinc:			
(B)	3.8	.86	3.3
(C)	4.3	.79	3.4
Petrocan	4.4	.9	4.0
CRS (U.S. only)	(3.5)	(.83)	(2.9)
IEA	4.3	.86	3.7

NA-Not available.

Note.—Several of the above studies include a high, medium, and low economic growth scenario. The Pirinc study has no base case as such, but provides 2 medium demand scenarios, one showing low economic growth with low-demand elasticity and one showing high economic growth with high-demand elasticity. Most studies do not include adequate data on developing nations.

Table 11 shows that the reason for the relatively high energy demand growth rates of the EIA, Petrocan, and IEA studies is related to assumptions of higher economic growth rates and lower demand elasticity in those studies.

Most of the above studies assume essentially constant real world oil prices.

NONOIL SUPPLY FORECASTS

Most studies treat oil as the "swing fuel," deducting all nonoil supply from total demand. Projections for nonoil energy supply in the free world are rather similar.

TABLE 12.—NONOIL ENERGY SUPPLIES IN 1985 AND 1990

[Million barrels per day oil equivalent]

	Natural gas		Coal		Nuclear		Other		Total	
	1985	1990	1985	1990	1985	1990	1985	1990	1985	1990
Exxon	19.2	21.6	24.0	29.7	7.6	12.5	9.1	11.7	59.9	75.5
EIA/DOE	19.0	NA	24.8	NA	6.7	NA	8.6	NA	59.1	NA
Petroleum Economics	21.4	24.9	21.0	25.1	7.5	13.6	8.9	11.3	58.8	74.9
Pirinc	21.0	24.4	22.6	25.8	8.1	13.6	7.8	9.1	59.5	72.9
Petrocan	20.2	23.3	22.4	26.3	8.0	13.0	8.3	9.9	58.9	72.5
CRS	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
IEA	(12.7)	(12.1)	(17.7)	(20.3)	(7.0)	(11.7)	(5.3)	(6.4)	(42.7)	(50.5)

NA = Not available.
(IEA members only.)

While the differences in natural gas supply are rather small, free world non-OPEC supply projections may even be closer than indicated in table 12. Some of the differences in supply estimates are due to inclusion of imported gas from the Soviet Union. It is known that Soviet gas exports to Europe are included in the PIRINC forecast, but neither of the other studies explicitly states whether such imports are included or not.

Differences in coal supply projections reflect mainly the uncertainty of coal demand in the United States and may also reflect inclusion of East bloc coal imports into Western Europe in some of the above studies.

NON-OPEC OIL SUPPLY IN 1985

TABLE 13.—NON-OPEC OIL SUPPLY IN 1985, 1990

[In million barrels per day]

	OECD		Non-OPEC LDC's		Total	
	1985	1990	1985	1990	1985	1990
Exxon	16.0	17.0	8.0	10.0	24.0	27.0
EIA/DOE	16.3	16.3	7.5	8.1	23.8	24.4
Petroleum Economics	17.0	18.7	8.5	10.2	25.5	28.9
Pirinc	16.1	17.8	7.5	9.7	24.4	27.5
Petrocan	17.2	17.6	7.7	8.9	24.9	26.5
CRS	17.3	19.1	7.7	8.3	25.0	27.4
IEA[1]	15.7	14.5	8.9	11.6	24.6	26.1

[1] France and Australia are members of OECD, but not of IEA. Of the two, Australia is an oil producer, which may be expected to produce up to 500,000 bbl/d in 1985 and 1990.

The difference between the high and low forecasts are 1.7 million bbl/d for 1985 and 3.0 million bbl/d by 1990. Given the leadtimes of 8 to 13 years and the size of the geographical area covered under table 13, the differences between the high and low estimates are not very significant.

Exxon, EIA, PIRINC, and the IEA are not very optimistic on U.S. oil supplies. Petroleum Economics, Petrocan, and CRS project U.S. oil production in 1985 to be 0.5 to 0.7 million bbl/d higher than the other studies.

Exxon, PIRINC, and Petrocan are also considerably more optimistic on North Sea production than the other four studies, and the International Energy Agency is rather pessimistic on the prospects for maintaining OECD oil production at 1985 levels through the remainder of the decade.

On non-OPEC LDC production, the differences between the low and high estimates are in particular noticeable for Mexico. Pessimists project 1985 Mexican oil production at about 2.5 million bbl/d in 1985; optimists believe that between 3.5 and 4.0 million bbl/d may be produced. The differences between low and high oil production estimates for 1990 again reflect largely differences in the outlook for Mexican production. Petrocan, for example, estimates Mexican's 1990 output at 2.6 million bbl/d whereas the IEA projects a production of 5 million bbl/d for the same year.

The difference in oil production estimates for the various subregions, reflect primarily differences in expectations of the analysts on geological prospects, prices. leadtimes, and Government policy. Regional oil projections are subject to continuous changes, but the ranges projected in table 13 reflect the most recent thinking of analysts in Government agencies and private industry.

CENTRALLY PLANNED ECONOMIES (CPE)

There are considerable differences in view between energy analysts on the energy outlook of the centrally planned economies. It would appear that most public and private organizations have great difficulty accepting the CIA thesis that the CPE nations will soon cease to be net exporters of oil, and will become net importers of free world oil.

None of the organizations whose forecasts are compared here have undertaken an elaborate analysis of Soviet oil demand and supply potential. The CIA, on the other hand, had made an impressive effort in this area. Most of the criticism is not related to the potential production shortfall in the Soviet bloc, but to the ability of the Soviet bloc to turn from a major earner or oil-related foreign exchange to a next oil importer. In other words, most critics believe that the Soviets have the ability to force conservation and interfuel substitution if oil production falls considerably short of current targets. The difference between the DOE/CIA forecasts and the Exxon projections translate into 3.2 million bbl/d additional demand for free world oil in 1985.

The 1985 forecasts of net CPE oil imports are:

TABLE 14.—CPE NET OIL IMPORTS

[In million barrels per day]

	1985	1990
Exxon	−1.0	−1.0
EIA/DOE	2.2	3.0
Petroleum Economics	.5	0
Pirinc	−.5	−.5
Petrocan	−.1	.1
CRS	−1.0	0
IEA	1.0	NA

NA=Not available.

TABLE 15.—COMPOSITE FREE WORLD ENERGY DEMAND AND SUPPLY, 1985 AND 1990

[In million barrels per day of oil equivalent]

		Exxon		EIA/DOE		Petroleum Economics		Pirinc		Petrocan		CRS		IEA	
	1976	1985	1990	1985	1990	1985	1990	1985	1990	1985	1990	1985	1990	1985	1990
Total demand	88.0	125.0	148.0	[1] 121.8	151.6	120.3	139.3	122.3	146.4	131.2	154.9	NA	NA	(118.0)	(139.1)
Annual GNP growth rate		3.8		4.1		NA		3.8–4.3		4.4		NA		(4.3)	
E/GNP multiplier		0.8		0.89		NA		0.86–0.79		0.9		NA		(0.86)	
Energy demand		4.3	4.5	3.6		3.0		3.3–3.4		4.0		NA		(3.7)	
Supply:															
Oil and natural gas liquids (non-OPEC)	16.1	24.0	27.0	23.8	24.4	25.5	28.9	24.4	27.5	25.4	27.0	25.0	27.4	(15.7)	(14.5)
Natural gas	15.3	19.2	21.6	19.0	NA	21.4	24.9	21.0	24.4	21.8	25.0	NA		(12.7)	(12.1)
Coal	15.3	24.0	29.7	24.8	NA	21.0	25.1	22.6	25.8	22.9	27.3	NA		(17.7)	(20.3)
Nuclear	2.2	7.6	12.5	6.7	NA	7.5	13.6	8.1	13.6	8.0	13.8	NA		(7.0)	(11.7)
Hydro/geothermal/other	7.1	9.1	11.7	8.6	NA	8.9	11.3	7.8	9.1	8.4	10.1	NA		(5.3)	(6.4)
CPE net oil imports	−1.4	−1.0	−1.0	2.2	3.0	0.5	0	−0.5	−0.5	−0.1	−0.3	−1.0	0	1.0	NA
Residual demand on OPEC oil	30.1	40.0	44.0	44.6	58.4	35.5	35.5	36.6	43.1	44.6	52.0	42.8	48.9	42.0–48.0	49.0
Projected OPEC production	30.1	40.0	44.0	36.8–38.8	36.5–43.5	35.5	35.5	36.6	43.1	44.6	52.0	(2)	(2)	36.0–38.0	37.9

[1] Satisfied demand.

[2] Not specified.

Note: Figures do not necessarily add due to rounding. Figures in brackets are for IEA countries only except for total demand which includes LDC's, but does not include Oceania, South Africa, and Israel.
NA=Not available.

Table 15 shows that three out of the seven studies project no supply tightening through the middle 1980's—Exxon, PIRINC and Petroleum Economics—in their base case free world demand and supply projections. There is much less certainty about the post-1985 situation. Optimists, like Exxon and PIRINC, assume that OPEC will meet world demand of 43–44 mmb/d without any significant upward pressure on the price. The EIA/DOE, Petrocan and IEA analysis project the possibility of substantial price increases (in real terms), in particular, if OPEC decides to keep production down to between 36 and 38 mmb/d.

High energy and economic growth cases have been eliminated from this report in order to simplify the comparison. If high-growth scenarios were added, almost all studies would project substantial upward pressure on prices in the early to middle 1980's.

OPEC OIL: DEMAND VERSUS SUPPLY

The OPEC cartel is the swing producer of oil in the free world. Any shortfall between free world non-OPEC energy demand and supply has so far been met with OPEC oil imports and some oil imports from the Soviet Union. Depending on the ability and willingness of OPEC to meet future free world shortfalls between energy demand and supply, prices could remain relatively stable (in real terms), or increase either gradually or sharply.

The seven studies examined here project the following level of OPEC supply required to meet world oil demand:

TABLE 16.—PROJECTIONS OF OPEC DEMAND AND SUPPLY IN 1985 AND 1990

[In million barrels per day]

Organizations (base cases only)	Required supply to meet world demand	
	1985	1990
Exxon	40.0	44.0
EIA/DOE	[1] 46.6	58.4
Petroleum Economics	35.5	35.5
PIRINC	36.6	43.1
Petrocan	44.6	52.0
CRS	[2] 42.8	[2] 48.9
IEA	[3] 43.0–48.0	[3] 49.0

[1] EIA/DOE projects demand for OPEC oil in 1985 at 44,600,000 (assumes no change in real price), but available supply at between 36,800.000 and 38,800,000 bbl/d. Demand on OPEC oil is estimated at 58,400,000 bbl/d in 1990, but only 36,500,000–43,500,000 bbl/d will be available.

[2] Required OPEC production to meet world demand. CRS does not specify available supply.

[3] Required OPEC production; available supply is estimated at between 36,000,000 and 38,000.000 bbl/d in 1985; total demand for OPEC oil at constant prices is estimated at 49,000.000 bbl/d, while OPEC sustained capacity is projected at 37,900,000 bbl/d.

CONCLUSION

This survey of seven recent (1978) world energy demand and supply forecasts is by no means complete, but it is fairly representative of recent thinking on the future of world energy demand and supply.

Compared with earlier studies (see tables 1–5) the recent surveys analyzed here show generally lower economic growth rates, higher demand elasticities, and lower non-OPEC energy supply expectations. On balance, the pessimistic views prevailing in post-embargo years have not altogether disappeared, but the timing has been changed (from the early or middle to the middle or late 1980's).

The main reason behind the somewhat more optimistic world energy outlook of most recent studies is the revised outlook for economic growth and energy consumption. It is not always clear whether current projections of lower economic growth rates reflect prevailing pessimism based on recent experiences, or if the industrial world is now entering into a new era of lower economic growth rates caused by demographic, technological, environmental and institutional changes. For the policymaker, it would seem too early to accept projections of lower economic growth as inevitable, in particular because such projections are generally accompanied with higher rates of unemployment.

The seven 1978 studies examined here also differ substantially on energy demand elasticity. Two of the studies assumed a multiplier (energy demand growth rate divided by GNP growth rates) of about 0.9 for the industrial world, while two others assume a multiplier of about 0.8. Under similar economic growth rates of say 4.2 percent per annum, the impact on energy demand of a multiplier of 0.8 or 0.9 is about 0.4 percent annually. This translates into a difference in free world energy demand of about 2 mmb/d in 1985 and 4 mmb/d by 1990.

In view of OPEC's current spare capacity of about 3 to 6 mmb/d, even small differences in economic growth rates and/or demand elasticities are likely to have a significant impact on world oil prices in the 1980's.

Given the uncertainties of reserve additions, investment decisions, environmental and institutional hurdles related to nonoil energy supplies in the free world, the seven studies are remarkably close in their projections through 1990 (see table 12). One would expect that the numerous uncertainties related to total free world nonoil energy production would have resulted in differences of at least 10 percent or more by the middle and late 1980's. To observe that actual differences are negligible for 1985 and less than 5 percent for 1990 makes one wonder if energy forecasters do not at times look over each others shoulders and agree on a base case not too far removed from the prevailing view.

On non-OPEC oil forecasts, one needs to take a separate look at projections for the OECD region and the developing countries. Differences between the highs and lows of OECD oil production forecasts—about 1.1 mmb/d in 1985 and 3.7 mmb/d in 1990—reflect primarily conflicting views on U.S. and North Sea oil production potential. Non-OPEC developing country production is projected at between 7.5 and 8.9 mmb/d in 1985 and 8.1 to 11.6 mmb/d for 1990. The differences between the highs and lows here are almost exclusively due to estimates of Mexican oil production for those years.

For all non-OPEC countries outside the Communist bloc, the seven studies are again rather close in their production estimates. The difference between the lowest and the highest estimates are only 1.7 mmb/d for 1985 and 4.5 mmb/d in 1990. A careful analysis of the seven studies would suggest that the high estimates tend to be unduly optimistic on U.S. production potential and the low estimates too pessimistic on Mexico's ability to rapidly increase production in the next decade. A medium estimate between the high and low projections would appear most realistic at this time.

The importance of oil developments in the Communist countries is once again highlighted in this comparison. The official U.S. Government data, in part based on the CIA analysis of oil production and consumption trends in all CPE's shows growing net CPE imports in the 1980's, while most other forecasts project continued CPE net exports. It goes without saying that the CIA analysis on CPE oil developments is the most elaborate available to date in the free world, and the main thesis of the CIA forecast has not yet been disproved by an equally convincing analysis by opponents of the study.

The difference between the DOE/CIA view and that of Exxon or CRS is quite substantial in terms of additional demand tor OPEC oil. While CRS and Exxon project net CPE exports of 1 mmb/d for 1985, the DOE/CIA analysis shows net imports of 2.2 mmb/d for the centrally planned economies; a difference of 3.2 mmb/d additional demand for OPEC oil.

Adding up domestic demand (base cases only) and supply for all non-OPEC countries in the free world, and adjusting net world oil imports for CPE estimates, a rather large difference in demand for OPEC oil projected in the seven studies.

If there were no constraints on OPEC oil production, differences between the lowest and highest demand for OPEC oil in the seven studies would be 12.5 million bbl/d in 1985 and 27.9 million bbl/d by 1990. However, few studies assume an OPEC production of more than 43 million bbl/d by the middle and late 1990's. Hence, the difference in estimates of demand on OPEC oil that might be satisfied can be reduced to 7.5 million bbl/d in 1985 and 1990.

Today, sustainable OPEC production capacity is approximately 36 million bbl/d, but no more than about 33 million bbl/d is actually available due to production constraints in some OPEC countries.

Exxon and PIRINC are quite confident that OPEC will expand productive capacity to meet world oil demand projected in their base case scenarios. EIA/DOE and IEA, on the other hand are very pessimistic, because they are convinced that OPEC will limit available capacity to between approximately 36 and 38 million bbl/d. The other studies express some doubt that OPEC will expand production sufficiently to meet projected demand by the middle 1980's and beyond.

Within OPEC, most Persian Gulf countries and Libya have adequate oil reserves to expand installed capacity and actual production. How many will actually do so in time to meet world demand in the future, is uncertain. Current sustainable production capacity of OPEC is about 36.6 million bbl/d. Demand for OPEC oil could reach this level in the early 1980's. In order to increase sustained production above this level, individual OPEC members will have to increase installed capacity, which now stands at about 41 million bbl/d. There is sufficient indication today that this is not now being contemplated. On the contrary, recent decision by Saudi Arabia to reduce output of Saudi light oil from about 80 to 65 percent, and the intention of the Saudi Government to ultimately bring production of light and heavy oil more in line with their actual reserve situation,would suggest that major expansion of production may be a long way off.

A cautious government or corporate planner is not likely to count on major expansion of OPEC sustained production. Instead, every effort should be made to enhance petroleum exploration and development elsewhere.

The difference between the CIA/DOE and PIRINC/Exxon view of future demand for OPEC oil and projected sustained production from the cartel translates in the final analysis into price movements. The latter show lower economic growth rates, higher demand elasticity and greater optimism in the performance of the CPE's and OPEC's willingness to produce more oil. Consequently, they project relatively stable oil price (in real terms) through the middle 1980's and small price increases thereafter.

The CIA/DOE base case scenarios cannot accept from the outside lower OECD economic growth rates than needed to maintain current rates of unemployment (about 17 million in the region). Moreover, CIA/DOE is somewhat less optimistic on energy demand elasticity for the OECD, less optimistic on OPEC's willingness to produce more oil, and pessimistic on CPE performance in maintaining net oil exports. Hence, unless corrective action is taken immediately, the CIA and DOE foresee increased demand for OPEC oil without significant growth in available OPEC oil production. Sometime in the early or middle 1980's free world oil supply will be so tight, according to this view, that a major OPEC oil price increase can no longer be avoided. Such a major price increase is likely to have a downward effect on free world GNP growth.

This view of world oil developments provided the rationale for the 1977 national energy plan. Conservation measures were seen as the only answer to exert downward pressure on oil prices in the short run, and conversion of industries and utilities away from oil and gas to coal and nuclear would do the same in the intermediate term (through the middle 1980's). The national energy supply strategy, currently being designed by DOE would provide the long-term response to the OPEC challenge by gradually replacing dwindling conventional sources of oil and gas with a variety of alternative energy systems. One has to accept the premise of the CIA/DOE view of world oil developments to accept the urgency of the national energy plan and the national energy supply strategy.

Chapter IV—U.S. Energy Projections: Three Scenarios

U.S. ENERGY DEMAND

Since 1955 U.S. energy demand has increased at an average annual rate of 3.2 percent per year. Total net energy demand grew from 35 quadrillion Btu (quads) in 1955 to about 72 quads in 1974. Following the 1975 recession, energy demand grew slowly to about 75 quads in 1977.

Most U.S. energy demand projections for 1985 range between 95 and 98 quads, depending on assumptions of economic growth and demand elasticity. The three U.S. energy demand and supply scenarios on table 17 represent a low, medium, and high energy growth case, which are fairly representative of current ranges of U.S. energy demand through 1990. The actual demand figures are based on the Project Interdependence energy study undertaken by the Congressional Research Service in 1977 and published in January 1978. Depending on optimistic or pessimistic assumptions of economic growth and energy demand elasticities, the CRS study projects energy demand to grow between 2.6 and 3.1 percent per year between 1977 and 1990.

OIL PRODUCTION

Estimates of undiscovered recoverable oil resources in the United States have undergone significant changes in recent years, ranging from a high of 590 billion barrels (USGS–Zapp, 1962) to a low of 74 billion barrels (Hubbert, 1974). The USGS published its most elaborate assessment of U.S. undiscovered recoverable oil resources in 1975. It estimates remaining recoverable oil resources at a minimum of 50 billion and a maximum of 127 billion barrels. Assuming that an additional 88 billion barrels will ultimately be found in the United States (mean between the high and low), the resource base itself is not likely to become the principal constraint.

The major constraint on increasing oil production in the United States is to find enough new fields to maintain or increase current production.

Until the late 1960's, additions to oil reserves exceeded production generally with a comfortable margin. Since 1967, however, reserve additions in the lower 48 States have been less than production. Because of earlier discoveries, output in the lower 48 States continued to increase until 1970, when it peaked at 3.2 billion barrels. In 1976 it had fallen to 2.8 billion barrels, a decline of more than 2 percent per year. Since 1971, reserve additions have averaged only 1.7 billion barrels per year, and it does not seem likely that the downward trend could be reversed in the lower 48 States. The national energy plan calls for oil production to rise to 10.6 million b/d in 1985. At a U.S. oil production level of 10.6 million b/d, or close to 4 billion barrels per year, the resource base will have to increase substantially.

The resource base and drilling effort needed to support a U.S. oil production of 4 billion barrels can be determined as follows: (1) assuming a gradual increase of production, about 34 billion barrels of oil will need to be produced from 1977–85 to achieve the 1985 target; (2) another 40 billion barrels of oil reserves will be needed to maintain a reserve-to-production ratio of 10 years. Lowering this ratio much will affect long-term recoverability of the oilfields.

Physical constraints limit annual withdrawals from oilfields to a volume about equal to a production-to-reserve ratio of approximately 1 to 10. This is an aggregate ratio; individual fields will vary above and below that ratio. We are currently producing about the maximum allowable from our proved reserves of about 30 billion barrels, or 3 billion barrels of oil per year.

To attain an oil production level of 4 billion barrels and maintain a reserve-to-production ratio of 10 to 1, about 74 billion barrels will be needed. Oil and NGL reserves were about 37.3 billion barrels at the end of 1976, and another 3 billion can be added for oil produced with advanced recovery techniques (estimate by National Petroleum Council). Thus, another 36.5 billion barrels (74.1 minus 37.6) will have to be added to reserves by the mid eighties to support a 4-billion barrel production level, while maintaining a 10-to-1 reserve ratio. In order to meet the desired production of 4 billion barrels in 1985 (with 40 billion barrels of reserves at the end of that year), about 4 billion barrels will have to be added annually for the next 9 years.

Since 1946 the bulk of the oil reserves in the lower 48 States were from extensions and revisions of existing fields. With oilfields getting older in the lower 48 States, much of the future discoveries in the lower 48 States will have to come from new fields. Some believe that higher prices will add significantly to reserves from enhanced recovery, but the National Petroleum Council maintains that the maximum to be expected from enhanced recovery from old wells is 0.6 billion barrels. Since 1948, there has only been 1 year that reserves had increased by more than 3 billion barrels (1971 Prudhoe Bay). In the absence of one or more giant discoveries in the frontier areas (Alaska and offshore Atlantic, Pacific, and Gulf of Mexico), it will be difficult if not impossible to achieve annual reserve additions of 3 to 4 billion barrels.

NATURAL GAS

Proved reserves of natural gas in the United States were at about 210 trillion cubic feet (TCF) at the end of 1977. This is the equivalent of about 11 years at the current rate of production. The 1977 figure was lower again than the estimate of the previous year when reserves stood at 216 TCF. Last year marked the 7th straight year of natural gas reserve decline, and the 10th consecutive drop in reserves in the lower 48 States.

Natural gas reserves are now at the lowest level since 1949, when production was only one-third of today's. In the 8 years from 1968 to 1976 annual average reserve additions were only 8.6 TCF. If reserve additions do not improve rapidly, the Nation will face an ever-growing natural gas crisis.

RUNNING OUT OF RESOURCES?

The total estimated U.S. natural gas resource base is not now the biggest problem. Estimates of undiscovered recoverable natural gas resources by the U.S. Geological Survey range from 322 to 655 TCF. Adding a probability analysis, the U.S. Geological Survey suggests that there is a 50-percent chance that the mean between the high and low—or 488 TCF—will be found eventually. This represents about 25 years of natural gas at today's rate of production.

FUTURE PRODUCTION AND RESERVE ADDITIONS

Recent production projections for 1985 range from low estimates of about 15 TCF to high estimates of 18 TCF. While a few are even higher than 18 TCF, recent studies no longer show the vast potential production increases characteristic of so many energy forecasts prior to the middle 1970's.

The total estimated resource base; that is, about 210 TCF of proved reserves and possibly another 488 TCF of undiscovered recoverable resources, provides about 35 years of supply at the current rate of production. The main question at this time is not whether the resources exist, but how much can be added to annual reserves to stabilize production.

If the discovery rate of the past 8 years were continued during the next 8 years, natural gas production in 1985 will be several trillion cubic feet below current production. A substantial improvement of finding rates is needed to maintain the current rate of production.

A brief look at required reserve additions may be useful to show the effort needed to attain the higher production estimate which is about 5 percent below current production.

To arrive at a dry gas production of 17.5 TCF in 1985, the following resource base will be required: (1) About 160 TCF of natural gas will probably be produced between 1977 and 1985 to arrive at the projected 1985 output level of 17.5 TCF; and (2) about 210 TCF will be needed to maintain a 12-to-1 reserve-to-production ratio. Hence, a little more than 17.5 TCF will have to be added to natural gas reserves every year between now and the end of 1985. Not since the North Slope discoveries has more than 17.5 TCF been added to reserves in any one year. Gradual decontrol of new gas may very well result in a considerable improvement of natural gas discoveries, substantially higher than the average of the past 8 years of 8.6 TCF—1968–76.

Prior to the middle 1980's nonconventional sources of natural gas are not likely to make a contribution to the Nation's output of natural gas, and there is still a considerable degree of uncertainty about the timing of an Alaskan natural gas pipeline.

In summary, it would appear that even with a substantial increase in drilling activity following gradual deregulation of new gas, and drawing down of gas reserves below the 12:1 R/P ratio, maintaining a production level through the middle 1980's close to the current rate of output will be very difficult. In order to meet the CRS high estimate of 17.5 TCF of dry natural gas by the middle 1980's with a

12:1 RP ratio, about one-third of the undiscovered recoverable resources of natural gas—USGS circular 725—will have to be found between now and the end of 1985.

COAL

Coal is the most abundant fossil fuel resource in the United States, constituting 90 percent of current total U.S. fossil fuel reserves. At today's level of coal demand, the United States has enough coal reserves to last several hundred years. Hence, coal reserves are not now a constraint on development.

Coal production in the United States peaked first in 1945, reached a low level of 435 million tons in 1960, rose thereafter again and leveled off in 1970–71 at 525 million tons. Following the Arab oil embargo, coal use grew once again, but not as rapidly as it could have due to demand constraints.

The high price of oil and expectations of higher gas prices in additional growing uncertainty about security of supply of imported oil; reduced domestic oil and natural gas supply prospects; serious conistraints on nuclear power development; and, Government polcy to discourage electric utilities and industry to burn oil or natural gas, have all contributed to the renewed interest in coal.

However, while there is general agreement among energy analysts that coal use has a bright future in the United States, most also agree that numerous problems associated with both the demand and supply of coal are likely to slow down domestic coal use through the middle 1980's to well below the 1,175 million tons projected in the 1977 national energy plan.

Domestic coal is likely to be limited by the following factors:

I. Industrial coal demand in the NEP

A. About 5 million barrels per day of oil equivalent out of a total of 13.3 million barrels per day of oil equivalent is the estimated industrial demand for coal under the NEP—2.7 million barrels per day oil equivalent without the plan. This is based on very high energy demand growth rates in the industrial sector, surpassing those of any comparable period in the recent history of the United States.

B. Strict implementation of the 1970 Clean Air Act with its 1977 amendments are likely to act as a serious constraint on domestic coal use with currently available technology.

C. Cost effectiveness of small coal-fired boilers for industrial use does not now compare favorably with oil-fired boilers, if scrubbers to control emissions are required.

II. Potential supply problems

A. Strip-mining provisions will limit future production expansion of surface-mined coal, in particular in smaller and medium-sized mines in the Eastern United States.

B. The requirement in NEP 1977 to use best available technology when burning coal, will lower demand for low-sulfur, but also low Btu Western coal, which is also further removed from the industrial centers of the country.

C. Trained manpower shortages for deep mining.

D. Labor-management relations, causing frequent supply interruptions of Eastern coal.

E. Continued decline of productivity since 1969, which is in part caused by attempts of operators to comply with safety and health regulations.

F. Transportation bottlenecks. Availability of larger rail cars and the capability of tracks to withstand the heavy loads caused by larger cars, may not be counted on. Truck and cargo traffic and coal slurry pipelines may also not be able to expand rapidly enough to meet transportation requirements.

G. Potential shortages of some mining and pollution abatement equipment.

H. Delays in Federal leasing of coal lands.

I. Water use problems in the West.

J. Institutional problems, in particular in the Western States.

Constraints on coal demand and supply are related to one another. Without assured markets, the coal industry is not likely to expand production capacity significantly. Hence, initially coal use expansion may continue to be primarily demand constraint, but if and when demand constraints are removed, a rapid search in coal demand may run up against numerous supply constraints listed here. In view of the above, the Congressional Research Service, the General Accounting Office, the Office of Technology Assessment and several nongovernmental research organizations have projected that U.S. coal use is likely to fall short of the 1985 target by a few 100 million tons, to below 1 billion tons per year.

NUCLEAR POWER

By the end of 1976, nuclear power provided less than 10 percent of the Nation's electricity—191 billion kilowatt-hours. By comparison, hydropower and natural gas supplied each about 14 percent, oil almost 16 percent, and coal about 46 percent of all electricity generated.

Projections on the future of nuclear power have changed markedly in the past decade. The Atomic Energy Commission's annual report in 1967 estimated a 1985 contribution of nuclear power of 255 gigawatts. Estimates continued to rise in the early 1970's. At one point, the Federal Energy Administration estimated that an accelerated nuclear program could contribute as much as 400 gigawatts capacity by 1985. But, after 1974–75 the early optimism of the potential contribution began to decline rapidly. Today, most studies project a U.S. nuclear capacity of slightly more than 100 gigawatts for their base case, with up to 125 gigawatts as a high estimate. Estimates of nuclear power capacity for 1990 and the year 2000 reached a peak in 1974 at respectively 750 and 1,500 gigawatts. Today, most estimates for 1990 range between 125 and 225 gigawatts, and Secretary Schlesinger's latest projections for the year 2000 are well below 400 gigawatts.

The large variations in forecasts during the last few years are an indication of the uncertainties surrounding the nuclear program.

Projections for the period up to 1985 are reasonably accurate. Actual nuclear capacity in the middle 1980's may vary somewhat, but no further major gyrations are likely to occur. Projections for the period beyond the middle 1980's are surrounded by enough economic, technical, and political uncertainties, to expect major changes in such estimates when additional information will become available. They cannot be trusted to give a reliable picture of the future beyond a few years.

While the biggest uncertainty of the long-term future of nuclear energy is related to cost-effectiveness, nuclear fuel uncertainties, and public acceptance, there are a number of other current and future constraints. These are listed in the table below.

LIST OF FACTORS LIKELY TO AFFECT THE FUTURE SUPPLY OF NUCLEAR ENERGY IN THE UNITED STATES

Factors	1977–85	1986–2000	2000
Public policy:			
National actions by the President and Congress	×	×	×
State government actions	×	×	×
Economic trends:			
Future growth in demand for electricity	×	×	×
Comparative costs of alternatives to nuclear power	×	×	×
Resources:			
Supplies of uranium	×	×	×
Supplies of thorium			×
Supplies of coal, oil and natural gas	×	×	×
Industrial capacity:			
Uranium mining and milling	×	×	
Uranium enrichment		×	×
Storage of spent fuel	×	×	?
Reprocessing of spent fuel	?	×	×
Management of high-level wastes	?	?	×
Technological developments:			
Development of the plutonium breeder		?	×
Development of acceptable plutonium recycle	?	×	×
Development of other ways to get more energy out of uranium which are also proliferation resistant		?	×
Regulation of burning of coal to generate electricity—by EPA and States	?	×	×
Regulation of nuclear energy:			
Economic—by State utility commissions	×	×	×
Environmental by NRC, EPA and States	?	×	×
Public health and safety—by NRC and EPA	×	×	×
National security (nonproliferation) by NRC	×	×	×
Siting—by NRC and States	×	×	×
Public opposition	×	?	?

×=expected effect.
?=possible but uncertain effect.

Source: Warren H. Donnelly, Congressional Research Service, 1977.

In general, the social, political, and regulatory factors appear to have more influence on future nuclear power developments than resource and technological factors. There is a danger that the current low level of new orders—if continued—could result in reduction of the present production capacity and subsequent contraction of the number of manufacturers. If that were to happen, future options to enlarge the presently projected expansion of nuclear power will be constrained for years.

OTHER DOMESTIC ENERGY SOURCES

Hydropower now provides about 14 percent of total electric generating capacity. In view of environmental and institutional constraints on the construction of hydroelectric dams and the long construction leadtime, major expansion of this energy source is not expected to take place during the next 15 years. Of all other alternative energy sources, synthetic gas, solar power, and to a lesser extent geothermal energy, are likely to make some contribution to domestic energy supply. In spite of the great promise each one of those energy sources holds for the long-term future, their contribution to total energy supply in the United States will remain very small through 1990.

PROJECTIONS OF U.S. ENERGY DEMAND AND SUPPLY THROUGH 1990

In a recent study of U.S. energy demand and supply by the Congressional Research Service, three energy demand scenarios were developed. A low, high, and medium (base case) demand scenario.[1] Total energy demand in the CRS study ranges from an oil equivalent of 43.0 to 46.4 million bbl/d in 1985, to between 49.4 and 53 6 million bbl/d by 1990.

This implies energy growth rates ranging from 2.5 to 3.1 percent per year and economic growth rates ranging from 3.2 to 3.5 percent per year. The total energy demand forecasts of the CRS study are in line with demand projections in the national energy plan (1977) and the more recent (April 1978) projections by the Energy Information Administration. Other recent projectons of U.S. energy demand by Petroleum Economics Ltd., the Central Intelligence Agency, MIT/WAES, and a number of oil companies are also close to the demand ranges in the CRS study.[2] Hence, for the purpose of this exercise, the CRS demand scenarios which are within the consensus ranges have been adopted.

On the supply side, three scenarios have been developed: a high, medium, and low supply case. Several additional scenarios can be developed by combining variations of domestic supply sources with different demand scenarios.

It is difficult to forecast with any degree of accuracy which one of the three scenarios in tables 17 and 18 or any other supply/demand combinations is the most probable. As we have seen in chapter II, projections of U.S. energy demand and supply for the middle 1980's have changed dramatically in the past few years. While most of the investment decisions affecting U.S. energy supply through the middle 1980's have already been made, there are still uncertainties in particular on actual production of liquid and solid fossil fuels. Furthermore, U.S. economic growth rates—which are affected by numerous internal and external factors—could be higher or lower than the average 3.2 to 3.5 percent estimated by the Congressional Research Service. Finally, differences in view on the volume of energy needed per unit of additional GNP (energy/GNP multiplier) are considerable. The CRS study estimates a multiplier of about 0.8 in 1985. Most studies show a multiplier close to the one in the Project Interdependence study, but the national energy plan assumes that much less energy is needed per unit of GNP growth. A few other studies believe the multiplier in the CRS study is too optimistic.

In view of these differences in opinion, it may be prudent—for Government planning purposes—to assume that domestic supply through 1985 and 1990 will be somewhere between the low and medium supply estimates in tables 17 and 18. The medium oil and natural gas supply case assumes that average annual additions to reserves will increase by about 50 percent over the experience of the past 7 years.

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[1] See U.S. Senate, "Project Interdependence: U.S. and World Energy Outlook Through 1990," Washington, D.C., November 1977 (officially released in January 1978), chap. II, pp. 108–129.

[2] While total energy demand in all of the quoted studies are close to the demand ranges in the CRS study, projections of economic growth rates and energy demand elasticity differ, but not substantially.

This will keep the production of liquid hydrocarbons relatively stable. The major increase in domestic supply in the low and medium supply case will have to come from coal and to a lesser extent nuclear power.

Domestic coal use is not subject to constraints on reserves and resources for one or more centuries to come. Coal use, hampered by environmental and institutional problems, is initially demand constrained, and may become supply constrained in the 1980's. The 920 million tons of domestic coal use in the medium supply scenario assumes that many constraints on coal use will be removed in the near future.

Nuclear power estimates in the three supply scenarios for 1985 are based on projections by the Congressional Research Service (Project Interdependence) and on more recent official counts by the Energy Information Administration.

In spite of considerable State and Federal support, solar and geothermal energy are not likely to make a major contribution to domestic energy supply prior to 1990. Of all synthetic fuels, coal gasification and shale oil are likely to reach the commercial stage on a small scale in the 1980's.

ENERGY IMPORTS

Under the energy demand and supply assumptions in table 17, only the high supply scenario would bring oil imports down by the middle 1980's. The low and medium supply scenarios coupled with low and medium demand would cause oil imports to increase to between 10.9 and 11.9 million bbl/d in 1985 (oil for strategic storage not included) and between 11.5 and 14.1 million bbl/d by 1990 (table 18).

Natural gas imports are estimated to double between now and 1985 (from about 0.9 to 1.8 trillion cubic feet) and could go up to 4 trillion cubic feet by 1990.

TABLE 17.—U.S. ENERGY DEMAND AND SUPPLY PROJECTIONS FOR 1985: 3 SCENARIOS

[In conventional units and million barrels per day oil equivalent]

	Low supply/low demand		Medium supply and demand		High supply/high demand	
	Conventional units	Million barrels per day oil equivalent	Conventional units	Million barrels per day oil equivalent	Conventional units	Million barrels per day oil equivalent
Total primary energy demand		43.0		44.8		46.4
Domestic supply:						
Oil and natural gas liquids (million barrels per day)	9.5	9.5	10.2	10.2	10.9	10.9
Natural gas (thousand cubic feet)	15.7	7.6	16.9	8.1	18.6	9.0
Coal (domestic use only) (million tons)	855.0	8.9	920.0	9.5	1,040.0	10.8
Nuclear power (gigawatts)	99.0	2.8	113.0	3.2	126.0	3.6
Hydro, solar, geothermal, and (quads)		1.5		1.9		2.5
Total domestic supply		30.3		32.9		36.8
Total energy imports		12.7		11.9		9.6
Natural gas (thousand cubic feet)	1.8	0.8	2.2	1.0	2.4	1.2
Crude oil and products		11.9		10.9		8.4

Note.—1,000 ft^3=1.025 quads. 100,000,000 short tons of coal in 1985=2.2 quads. Assumes 60 percent of design capacity used. 1 Kwh=10,660 Btus.

TABLE 18.—U.S. ENERGY DEMAND AND SUPPLY PROJECTIONS FOR 1990: 3 SCENARIOS

[In conventional units and million barrels per day oil equivalent]

	Low supply/low demand		Medium supply and demand		High supply/high demand	
	Conventional units	Million barrels per day oil equivalent	Conventional units	Million barrels per day oil equivalent	Conventional units	Million barrels per day oil equivalent
Total primary energy demand		49.4		51.5		53.6
Domestic supply:						
Oil and natural gas liquids (million barrels per day)	10.1	10.1	11.4	11.4	13.2	13.2
Natural Gas (thousand cubic feet)	15.5	7.5	16.9	8.1	17.4	4.8
Coal (domestic use only) (short tons)	1,020.0	10.5	1,135.0	11.7	1,250.0	12.9
Nuclear power (gigawatts)	130.0	3.6	170.0	4.8	190.0	.4
Hydro, solar, geothermal, and other (quads)	4.5	2.1	5.0	2.3	8.0	3.7
Total domestic supply		33.8		38.3		42.4
Total energy imports		15.6		13.2		10.0
Natural gas (thousand cubic feet)	3.0	1.5	3.6	1.7	4	1.9
Oil (crude and products)		14.1		11.5		8.1

Note: 1,000 ft^3=1.025 quads. 100,000,000 short tons of coal in 1985=2.2 quads. Assumes 65 percent of design capacity used. 1 kWh=10,660 Btu's.

CONCLUSION

The U.S. domestic energy outlook through 1985 and 1990 remains highly uncertain. Total energy demand in the three cases in tables 17 and 18 show a difference of about 3.5 million barrels per day between the low and high forecasts for 1985, and just above 4 million barrels per day by 1990. On the domestic supply side, there is a difference of 6.5 million barrels per day between the low and high case for 1985 and about 8.5 million barrels per day by 1980.

Natural gas imports in 1985 may range between 1.8 and 2.4 trillion cubic feet and between 3 and 4 trillion cubic feet by 1990. The optimistic gas import figures include a substantial volume of Mexican gas and stabilization of Canadian imports.

Given today's knowledge of oil and natural gas drilling and finding rates, one cannot but conclude that the careful policymaker would plan for the low or medium supply cases in tables 17 and 18. In particular, the high oil supply scenario for 1985 and 1990 now appears highly unrealistic, because it assumes a doubling of the historical rate of reserve addition. Moreover, in spite of improved prospects for natural gas reserve additions following the implementation of the National Energy Act, the prudent planner would not count on much more than stabilization of gas production in the United States. Even that would require an almost doubling of reserve addition of the early and middle 1970's.

Coal use is primarily demand constrained, and whether the low or medium volume will, in fact, be consumed will depend on a number of variables, such as: total demand for electricity; completion of nuclear powerplants; siting and other environmental problems; and, finally, financial and institutional problems. Short of lengthy delays caused by litigation related to environmental and institutional concerns, the medium supply case appears within reach.

The most recent count of nuclear powerplants under construction suggest that both the low and medium nuclear power supply scenario for 1985 are reasonable. The high supply case is not impossible, but does not appear likely at this time. The future of nuclear power beyond the middle 1980's is highly uncertain due to numerous constraints on licensing and construction of new powerplants. Each one of the three nuclear supply scenarios for 1990 are possible, but unless outstanding technical, financial, and institutional issues are resolved, the low and medium supply cases appear most probable. Of all nonconventional sources of energy, solar synthetic gas and shale oil offer fair to good prospects for the period through 1990, but, as a percentage of total 1985 and 1990 energy consumption, the contributions of these energy sources is likely to remain modest.

If U.S. oil and gas imports were to develop in the direction of the low and medium supply and demand cases in tables 17 and 18, the country will become more dependent on the rest of the world. The United States would need to restructure its economy and export a larger percent of its GDP than it does today. Aside from the national security problems related to growing dependence on imported oil, restructuring of the economy to pay for the additional oil imports will not be easy in a world environment of growing competition in the manufacturing sector of the economy.

To maintain oil imports at current levels or to reduce it by the middle 1980's and beyond, the United States can opt for additional conservation by means of higher energy prices (including Btu taxes) or emphasize supply. The former could have the effect of reducing economic growth rates; the latter could have an adverse impact on the environment and/or be costly in terms of Government price support for alternative energy systems (synfuels, solar, and others). Policymakers will have to weigh the total costs and benefits (including the national security costs) of growing dependence on foreign oil, and determine the amount of insurance the Nation is willing to buy to hedge against future uncertainties.

CHAPTER V—WORLD OIL DEMAND AND SUPPLY THROUGH 1990

INTRODUCTION

Free world consumption of oil has grown rapidly throughout the post-war era. Consumption more than doubled between 1960 and 1970, from 18.6 million bbl/d in 1960 to 39.5 million bbl/d in 1970. If the doubling trend of the 1950's and 1960's had continued in the 1970's, oil consumption in the free world would have reached 80 million bbl/d in 1980. Existing information on reserves and ultimate recoverable oil resources would suggest that if the oil consumption growth rates of previous decades would have prevailed in the 1970's, world oil production would have peaked in the early 1980's, even if all OPEC countries had continued to expand production to meet world demand.

The quadrupling of the price of oil in 1973–74, which was made possible during the Arab oil embargo following the Arab-Israeli war, contributed to the severe recession of 1974–75 in the free world. While the United States recovered from the recession in 1975, Western Europe and Japan are still substantially below their preembargo economic growth rates.

On the basis of post World War II oil consumption growth rates, and our knowledge of oil reserve additions in the free world, a continuation of the oil consumption growth rates of the preembargo era, would have resulted in large oil price increases no later than the early 1980's, when oil production would have reached its physical limits. The quadrupling of the world market price of oil, while causing initial hardship to the economies of the industrial nations, gave us the breathing spell we need to reconsider our energy policies, and reexamine the future prospects of oil consumption under acceptable economic growth scenarios. There is enough evidence to suggest that higher oil prices would have been inevitable even if an embargo and the subsequent major OPEC price hike had not taken place in 1973–74, and there is general agreement among energy experts that slower economic growth rates, higher oil prices, and mandatory conservation measures enacted after the 1973–74 embargo, will reduce oil consumption growth rates considerably in the OECD countries.

WORLD OIL RESERVES

In December 1977, world oil reserves were estimated at about 646 billion barrels. Free world reserves now amount to some 548 billion barrels. At the current free world rate of oil consumption, these reserves are equal to about 30 years of consumption.

TABLE 19.—*World Oil Reserves, by Region*

Africa	59. 2
Asia-Pacific	19. 7
Western Europe	26. 9
Middle East	366. 1
Western Hemisphere	75. 8
Total free world	547. 7
Communist bloc	98
Total	645. 7

Source: Oil and Gas Journal, Dec. 26, 1977.

RESOURCES

Total world oil resources are estimated in most recent studies by eminent geologists at about 2,000 billion barrels.[1] The 2,000 billion barrels of ultimate recoverable resources include current world reserves of about 646 billion barrels and cumulative production of approximately 360 billion barrels (December 1977). Hence, about half of the ultimate recoverable oil resources remain to be discovered.

Unfortunately, the concentration of not yet discovered oil resources in the world may not be much more favorable to the industrial nations that the distribution of current reserves (see fig. 13). The main difference between the geographical distribution of current oil reserves and ultimate recoverable resources, is in the larger potential resource base of the Communist countries. Much of the Soviet and Chinese oil potential, however, is located in hostile physical environments, such as the Arctic and in offshore areas.

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[1] For references to studies by John Moody, Lewis Weeks, M. King Hubbert and others on world oil resources, see: M. King Hubbert, "World Oil and Natural Gas Reserves and Resources," in Project Interdependence: U.S. and World Energy Outlook Through 1990, U.S. Congress, Washington, D.C., November 1977, p. 638.

Figure 13.—World Oil Reserves by Region (in billions of barrels)

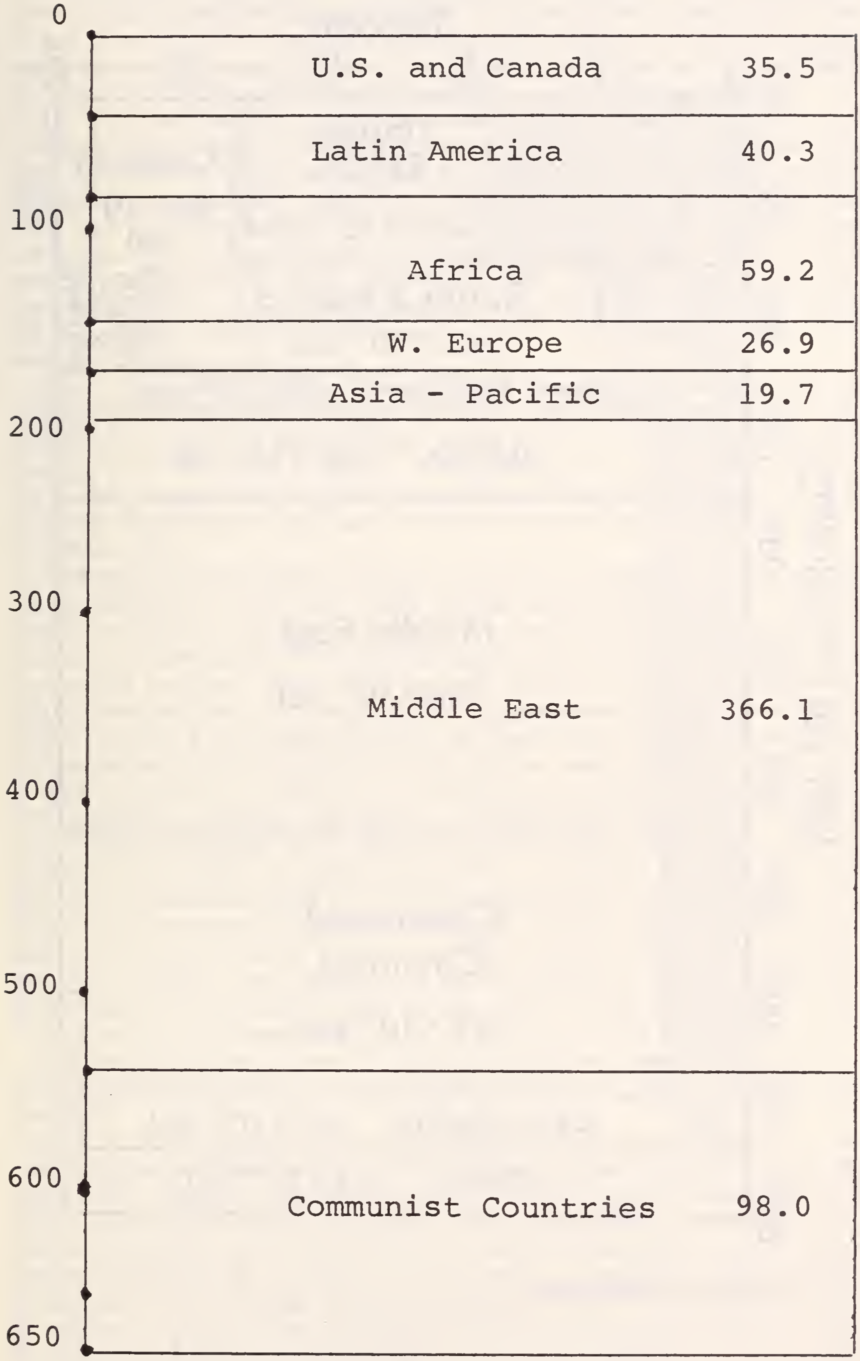
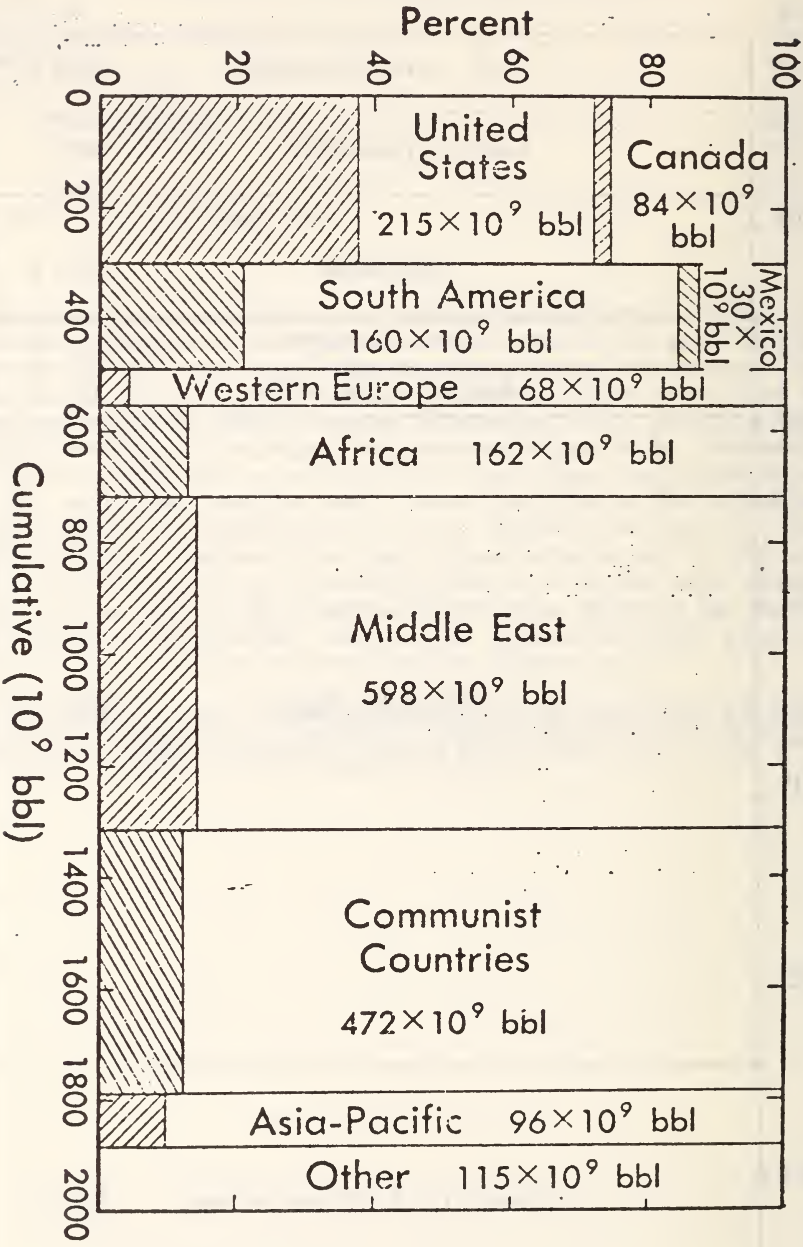


FIGURE 14.—World Oil Resources by Region



Source: M. King Hubbert.

Figure 14 suggests that the industrial countries of the free world will continue to be largely dependent on OPEC and non-OPEC developing countries for most of their oil supplies. The Middle East is not expected to unveil vast new oil fields, and most of the estimated undiscovered recoverable resources in that part of the world may have to come from extension of existing fields and smaller new fields.

On the basis of the potential resource base alone, it is difficult to project future rates of oil discoveries. During the past quarter of a century, reserve additions in the free world have averaged some 20 billion barrels per year, well above the rate of world oil consumption. The high rate annual finding rate included initial discoveries and later revisions of the huge oil fields in the Middle East. After 1970 when no new supergiant fields were discovered in the Middle East, free world reserve additions have averaged less than 15 billion barrels per year. This is several billion barrels per year below the current rate of free world oil consumption.

Most geologists believe that Middle East-type reservoirs are so unique, that one cannot expect to find similar geological conditions elsewhere in the free world. That is not to say that Mexico or North Sea-type oil discoveries cannot be expected to occur from time to time. But, in general, future discoveries are likely to be smaller than Middle East-type fields and in more remote and hostile physical environments.

The importance of this conclusion cannot be overestimated. Current oil production in the free world comes from some 30,000 fields. Of these, 240 fields hold 73 percent of the free world reserves; 15 fields contain 34 percent of the reserves; and 4 fields hold one-fifth of total free world reserves. Most of today's oil production outside the United States comes from very large fields which are becoming increasingly difficult to find in numbers needed to meet future world oil demand. To maintain reserve additions of 20 billion barrels per year (average of past quarter of a century), worldwide petroleum exploration and development programs will have to become more extensive and much more successful than they have been in recent years, when reserve additions averaged no more than about 15 billion barrels per year. Assuming that about half of the future discoveries will come from new fields and extension of existing fields in OPEC countires, the other half will have to come from non-OPEC developed and developing countries. There are a number of limiting factors other than the resource base, which may stand in the way of adding as much as 20 billion barrels to reserves annually in the free world. These are:

1. Discovery rates: much of the remaining resource base is scattered around the world; Much of it in hostile areas far away from the major markets.
2. Size of discovered reservoirs: While there are likely to be some North Slope or Mexico-type oil discoveries in the future, much of the remaining resource base is expected to be in smaller accumulations. While each small field (assuming its development is economically viable) may earn good profits for individual companies and improve the balance of trade of individual countries, one needs to find 15 fields of the size of East Texas the second largest field in the United States) to achieve a production potential similar to current production from the Ghawar Field in Saudi Arabia (the largest oil field in the world).
3. Uncertainty about investment decisions in OPEC and non-OPEC developing countires for oil exploration and development.

4. Legal impediments: Much of the undiscovered recoverable oil in the free world is likely to be located offshore beneath the continental margins. Many potentially petroliferous offshore formations are in disputed areas, such as the vicinity of the Falkland Islands, the Spratly, Paracels and Senkaku Island groups, Spitsbergen, the Aegean Islands, and so on.

For these and possible other reasons, it may be optimistic to assume that the free world will continue to add 20 billion barrels to oil reserves annually. If it does not, the free world will increasingly have to draw on existing reserves to meet world demand (1977 at about 18 billion barrels), and that would mean that the reserve/production ratio would decline rapidly in the future.

OPEC AND NON-OPEC OIL SUPPLY: DIFFERENCES IN RESERVE TO PRODUCTION (R/P) RATIOS

In the United States the crude oil r/p ratio over the last 30 years ranged from slightly more than 9 to 1 to nearly 14 to 1. At the end of 1977 it was 10 to 1. In contrast, the Saudi r/p ratio in 1965 was 82 to 1, and by 1977, it had declined to 43 to 1. Among the world's leading oil producing countries r/p ratios differ substantially.

The United States is the third largest oil producer in the world and it has the lowest r/p ratio of the major oil producers. This is mainly due to the fact that most oil fields in the United States are in their depletion phase, and demand for oil has resulted in a relatively high-production performance. The drive to maximize income has at times resulted in poor reservoir depletion and ultimately, both resource and economic waste.

Saudi Arabia and several other large OPEC producing nations could produce much more oil than they are currently producing. The resource base is not now a constraint on production. Economic and political criteria, however, determine the extent of the installation of production and handling facilities. Countries with a relatively small capital absorptive capacity in relation to their potential production from known reserves, may want to protect the "national heritage" for the next generations. In most instances the lower production rates do have the effect of maximizing resource recovery.

About two-thirds of the current oil reserves and a substantial portion of projected future world oil discoveries are located in the Middle East and North Africa, and most of it in countries which do not necessarily perceive it in their interest to make the necessary investments to increase production to meet world demand.

If those key OPEC countries do not make the investments required to increase productive capacity (for technical, economic, or political reasons) sufficiently to meet future world demand, free world oil production is likely to peak sometime in the 1980's. Depending on free world economic growth rates, oil demand elasticity, non-OPEC oil supplies, and actual OPEC oil production, free world oil production could peak as early as the early or middle 1980's, or as late as the early 1990's.

Projections for OPEC sustained production capacity for the middle 1980's range from a low of about 35 million bbl/d to a high of a little more than 40 million bbl/d. Non-OPEC free world production is estimated to increase from about 20 million bbl/d today to approximately 21 to 28 million bbl/d in 1985, and the Communist bloc may export about 0.5 million bbl/d or import up to 2.5 million bbl/d by 1985. OPEC sustainable production capacity is not expected to grow much between 1985 and 1990. In some countries, production will have peaked and in other member States governments are likely to limit output well below physical capacity. On balance, OPEC sustained production capacity could be between about 34 and 41 million bbl/d in 1985 and between 36 and about 43 million bbl/d by 1990. Non-OPEC sustained production is expected to rise from the 21 to 28 million bbl/d range in 1985 to between about 24 and 31 million bbl/d in 1990 (see tables 21 and 22).

FREE WORLD OIL DEMAND

Free world oil demand is a function of economic growth rates, energy demand elasticity, interfuel substitution, and oil prices. Until recently, most energy forecasts assumed annual economic growth rates of more than 4% for the OECD countries, and a very slow decline in the energy/gnp growth elasticity.

Of late, earlier optimistic economic growth forecasts have made place for a generally more pessimistic outlook on the future of the world economy. As a result of these low economic growth forecasts, projections of future energy demand have also declined. Moreover, there is a little more optimism today about the ability of the economy to grow with lesser inputs of energy per unit of additional gnp than was generally thought likely a few years ago.

While energy growth rates per unit of additional gnp have indeed declined in most of the OECD countries, the experience of the past 2 to 3 years are by no means adequate for extrapolation into the future. The generally depressed state of many energy-intensive industries in the OECD countries may be a partial explanation of the higher energy demand elasticity in the past few years. But, it is primarily the adjustment to the high post-embargo world oil prices which caused the decline in the energy/GNP growth ratio in recent years. After this initial conservation response, it is possible that additional savings may have to come from the lengthy process of replacing energy-inefficient with energy-efficient capital goods. If this is the case, the long-term energy elasticity of demand will decline at a much slower pace than the experience of the past few years. Only time can tell what will actually happen.

Energy projections by Government agencies and congressional committees with responsibility to provide adequate energy to fuel the Nation's economy and to prevent a plethora of special relationships between oil importing and exporting countries, must be careful to include reasonable ranges of possible energy scenarios. Such energy scenarios must be based on acceptable projections of economic growth. Governments have long-term objectives of economic growth, reflecting social and political realities in their countries. While some non-governmental energy forecasts in recent months have projected very low economic growth rates for the free world through 1985 and subsequently also projected low energy demand growth throughout much of the 1980's, such tradeoffs are clearly unacceptable to the United States and most other governments in the industrial world. Low economic growth rates cause higher rates of unemployment or underemployment—in particular in Japan—in the industrial world with potentially disruptive political effects. Moreover, low economic growth rates in the industrial world will reduce imports of raw materials from developing countries and are likely to lead to growing demand for protectionist measures in the industrial countries against industrial products of the developing world. The net result would be further economic stagnation or very slow growth for the hundreds of millions in the developing world. It is not difficult to imagine the destablizing effect this would have on the political systems of the world and ultimately on major power relationships. Hence, while the tools of the science of economics cannot accurately project the long-term performance of the world economy, energy projections need assume that governments will do all they can to maintain acceptable economic growth rates. In our base-case world oil demand outlook we have assumed annual economic growth rates of about 4 percent in the OECD countries and about 5.5 percent per year in the developing countries—including OPEC. Energy/GNP growth elasticity in the entire free world is expected to decline from about 1.2 to 0.9, with most of the savings taking place in the OECD countries.

WORLD OIL DEMAND, 1985 AND 1990

During most of the quarter of a century prior to the 1973–74 quadrupling of the world market price of oil demand rose at annual rates of about 7 percent. A combination of higher prices, mandatory conservation, somewhat lower economic growth rates, and Government efforts to speed-up conversion away from oil to coal, nuclear, solar, and other alternative energy sources, will bring oil demand growth rates down substantially below pre-1973 levels, when oil was cheap and the resource base considered virtually without limits.

Few recent studies now project oil demand for the next decade or beyond to increase at anywhere near the average annual pre-1973 growth rates of 7 percent.

On the higher end of the demand curve, an annual growth rate of 4 percent until the middle 1980's followed by 3.5 percent per year through 1990 seems a reasonable estimate. On the lower end of the demand curve, an annual growth rate of 3 percent until 1985 and 2.5 percent per year thereafter until 1990, is still consistent with acceptable economic growth rates and substantial interfuel substitution. Some analysts see even more room for conservation and interfuel substitution. On the other hand, there are a number of studies projecting world oil demand to rise at annual rates of more than 4 percent at least through 1985.

TABLE 20.—SCENARIOS OF WORLD OIL DEMAND AND SUPPLY[1] IN 1985 AND 1990

	1985			1990		
	High	Low	Low-low	High	Low	Low-low
Free world demand (million barrels per day)	68.4	63.4	59.0	78.2	71.8	66.8
Annual increase (percentage)	4.0	3.0	2.2	3.5	2.5	2.5

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[1] The high and low oil demand projections for 1985 and 1990 are representative for most of the world energy forecast discussed in earlier chapters.

FREE WORLD OIL SUPPLY

Non-OPEC

The following factors have an impact on non-OPEC oil production between now and 1990:

—The size and degree of success of oil exploration and development programs;

—Removal of legal and political impediments to oil exploration and development;

—Location of reserve additions and leadtimes required to bring oil to the market;

—Ability of producer states to obtain the necessary capital and overcome development bottlenecks;

—The rate of production allowed by the owners of the resources; and

—Luck! In spite of significant advances in the state of the art of geological and geophysical surveys, in the final analysis oil drillers also depend on luck to find structures containing oil in commercial quantities.

Depending on these and possibly factors not listed here, non-OPEC oil production for 1985 is likely to be somewhere between a low of 22 million barrels per day and a high of about 28 million barrels per day. The high and low production for 1990 is estimated at respectively 31.2 and 23.7 million barrels per day. Actual output will probably be somewhere between the projected high and low output levels.

TABLE 21.—TWO SCENARIOS OF POSSIBLE NON-OPEC OIL PRODUCTION IN 1985 AND 1990

[In million barrels per day]

Non-OPEC oil supply	1985		1990	
	High	Low	High	Low
OECD:				
United States	10,9	9.5	11.4	10.1
Canada	1.9	1.5	1.9	1.4
United Kingdom	3.0	2.4	3.0	2.3
Norway	1.3	.9	1.6	1.3
Other OECD Europe	.5	.4	.5	.4
Other developed countries	4.	.4	.4	.3
Subtotal OECD and other DC's	18.0	15.1	18.8	15.8
LDC's:				
Mexico	3.5	2.3	5.0	2.5
Other Latin America	1.9	1.6	2.4	1.8
Egypt	1.0	.8	1.3	1.0
Other Africa	.7	.5	1.0	.7
Asia	2.4	1.7	2.7	1.9
Subtotal non-OPEC LDC's	9.5	6.9	12.4	7.9
Total non-OPEC supply	27.5	22.0	31.2	23.7

OPEC OIL PRODUCTION

During the 1960's, OPEC was primarily concerned with maintaining the level of posted price for their crude oils, which determined the producer governments' revenue. Conflicts between producer governments and the oil companies on posted prices in the early 1970's culminated in the dramatic price rises of 1973 and 1974. Producer governments were able to increase their revenues more than tenfold between 1970 and 1976; actual OPEC oil prices rose slightly less.

Having acquired control over world oil prices, OPEC governments turned their attention to obtaining participation and later full nationalization in the producing operations in their countries. This process has now almost been completed.

These changes have had and will continue to have a profound effect on oil supplies and prices. While oil companies are guided almost exclusively by commercial imperatives, consumer nations have learned that producer state governments base their decisions on output levels and prices on noncommercial criteria as well. Moreover, the size of proved reserves and estimated revenue requirements differ greatly among the OPEC members. It is clear that Saudi Arabia with a reserve/production ratio of about 50 years (if one includes probable reserves) and vast annual petrodollar surpluses even at the current rate of production, will have different output and pricing options than Indonesia, which has a reserve/production ratio of 17 years and an almost unlimited capital absorptive capacity.

OPEC nations do, however, share a common goal in maintaining their recently acquired pricing power, and they are likely to continue to exercise this power to some extent within the constraints of the market mechanism. Only a prolonged severe economic recession in the industrial world or a combination of major new oil finds outside OPEC and successful implementation on a large scale of conversion from oil to coal, nuclear, and other energy sources, could seriously challenge the pricing power of OPEC.

TWO OPEC PRODUCTION SCENARIOS FOR THE FUTURE

The level of OPEC oil production is based on the same criteria described before for the non-OPEC countries, and on the following factors:

—Technical limitation on production from producing fields;
—Capital absorptive capacity of major OPEC countries over time;
—Timely investment decisions by individual OPEC nations to have production and handling facilities ready when needed;
—Perception of individual OPEC producers of optimization of long-term income from their oil resources; and, last, but not least,
—Political and strategic factors.

On the basis of these variables, a number of credible OPEC production scenarios can be constructed. Current knowledge of technical, economic, and political criteria entering into the decisionmaking process of individual producers, leads one to believe that OPEC is likely to produce between about 35 and 41 million barrels per day in 1985, and between 36 and 43 million barrels per day by 1990. It is difficult, if not impossible, to be any more precise given the uncertainty of the variables determining actual output in each country. The difference between the high and the low production levels could, however, prove to have an important impact on world oil prices.

TABLE 22.—OPEC SUSTAINED PRODUCTION POSSIBILITIES: 1985 AND 1990: 2 SCENARIOS

	Oil reserves December 1977 (in billion barrels)	Production[1] possibilities (in million barrels per day)			
		1985		1990	
		Low	High	Low	High
Algeria	6.6	1.2	1.4	1.0	1.2
Ecuador	1.6	.3	.3	.2	.3
Gabon	2.0	.2	.3	.2	.3
Indonesia	10.0	1.7	1.9	1.5	1.9
Iran	62.0	5.0	6.2	4.5	5.5
Iraq	34.5	3.5	4.5	4.5	5.5
Kuwait	67.0	2.3	3.3	2.5	3.3
Libya	25.0	2.4	2.5	2.5	2.8
Nigeria	18.7	2.3	2.5	2.0	2.5
Qatar	5.6	.5	.6	.4	.5
Saudi Arabia	150.0	10.5	12.5	12.5	14.0
United Arab Emirates	31.0	2.3	2.9	2.5	3.0
Venezuela	18.2	2.1	2.3	1.7	2.3
Total	432.2	34.4	41.2	36.0	43.1
Net export Soviet bloc		0	−2.5	0	−2.5
Net export PRC		.5	1.0	.5	1.0

[1] Includes natural gas liquids.

PRICE MOVEMENTS

There is some agreement among oil market analysts that oil prices are not likely to increase much in real terms in the next few years. Low economic growth rates in Europe and Japan, higher than expected energy conservation, about 3 to 6 million barrels per day OPEC spare capacity, and substantial volumes of new production from Alaska, the North Sea, and Mexico, all conspire against any move by the cartel to raise prices significantly. In the current soft oil market, an attempt by OPEC to increase prices significantly could further dampen demand for OPEC oil, and this—in turn—would lead to price shaving by most producers. Only a strict prorationing scheme could protect substantially higher prices in today's market.

Assuming economic recovery in Western Europe and Japan and maintenance of current economic growth rates in the United States (about 4 percent per year), demand for OPEC oil could get close to available supply by the middle 1980's. In anticipation, prices are likely to rise in real terms before OPEC spare capacity runs out. There is no generally accepted model in existence today that can provide us with adequate information on price movements under various demand/supply scenarios. Most models attempting to measure price impact fail to provide adequate information on the effects of each price rise on world GNP growth rates. This is an important shortcoming, because it does not show the connection between price increases, GNP growth rates, and subsequent changes in oil demand.

The extent of future price movements will largely depend on the demand for and availability of OPEC oil. The following scenarios based on world oil demand and supply (OPEC and non-OPEC) will provide some indication of possible price movements.

1985

1. Low demand (63.4 million barrels per day) and high non-OPEC supply (27.9 million barrels per day) would require an OPEC production of 35.5 million barrels per day). Only if OPEC production will turn out to be on the low end of our projections, a real price increase could be expected under this scenario.

2. Low demand (63.4 million barrels per day) and low non-OPEC supply (21 million barrels per day) would require an OPEC production of 42.4 million barrels per day. With OPEC production in 1985 estimated at between 34.4 and 41.2 million barrels per day, this scenario would almost certainly lead to an increase in the real price of oil.

3. Intermediate demand (65.9 million barrels per day) and intermediate non-OPEC supply (about 24.9 million barrels per day), would require an OPEC production of 41 million barrels per day by 1985. Only under the high OPEC supply scenario would prices remain constant in real terms. If OPEC would supply less than 41 million barrels per day, real prices would rise.

1990

1. Low demand (71.8 million barrels per day) and high non-OPEC supply (31.2 million barrels per day) would require an OPEC production of 40.6 million barrels per day. If OPEC produces close to the high output level estimated in our OPEC production scenario, real prices could remain unchanged. At the low production level, real prices would have to rise.

2. High demand (78.2 million barrels per day) and low non-OPEC production of 54.5 million barrels per day. Under any OPEC production scenario, real prices would rise significantly.

3. Intermediate demand (75 million barrels per day) and intermediate non-OPEC supply (27.4 million barrels per day) would require an OPEC production of 47.6 million barrels per day. Under any of our OPEC supply scenarios, prices would rise significantly.

Several other scenarios are possible, most suggesting increases in the real price of oil before the middle 1980's.

Because it is so difficult to estimate oil price increases with existing tools available to economists, most energy projections assume either no change in the real price of oil through the middle 1980's, or only a slight annual increase of no more than 2 percent. Some analysts have ventured to estimate price increases through 1990, and suggest a 50-percent increase in the real price of oil between now and 1990. A few have assumed real prices to double between now and 1990, and one or two models suggest that a doubling of the real price of oil by 1985 is a distinct possibility. Some distinguished economists have argued that the world can adjust to a doubling of the price of oil by 1985, assuming increases are gradual. Other equally distinguished economists, foresee serious troubles for the world monetary system and for free world economic growth prospects in the event the real price of world oil doubles between now and the middle 1980's.

A WORLD OF UNCERTAINITIES

There are too many unknowns to enable petroleum economists to estimate future oil price movements with any degree of accuracy. We are aware of our limitations in projecting economic growth patterns, energy demand and long-term supply elasticities. In view of the diversity of interests within OPEC, it is difficult to gauge OPEC output and pricing behavior. Economic interest of the cartel are interwoven with political and strategic considerations of key suppliers, who alone—or in concert with one more actors—can influence pricing decisions.

Little is known about the long-term effects of significant increases of the real price of oil on the international monetary system and on world economic growth rates. We have some understanding of the effects of the 1973–74 oil price rises on world economic growth and inflation, but economists are divided on the potential impact of another series of major price increases on the world economy.

Finally, energy analysts are divided on the issue of Soviet bloc oil trade. Few have undertaken intensive research on this subject, but most assume that the Soviet bloc cannot afford to import much oil from the free world due to foreign exchange constraints. The Central Intelligence Agency, on the other hand, is convinced that the U.S.S.R. will fall dramatically short of production targets in the early and middle 1980's, resulting in Soviet bloc oil imports of up to 2.5 million b/d from the free world. In payment for the additional oil they would export more natural gas to Europe, more raw materials to all industrial nations, and possibly increase sales of sophisticated armament at a time when the United States is trying to reduce its arms sales.

Soviet bloc oil imports of up to 2.5 million b/d by 1985 could drive the world oil price up significantly even under our scenario of low free world oil demand growth and high non-OPEC supply.

Other uncertainties, such as temporary supply interruptions in major producer states due to natural or manmade calamities, could have an important bearing on the price of oil even today, because the available OPEC surplus is not much more than 3.0 million b/d.

For some time to come the world will have to live with growing supply and price uncertainities until the industrial nations show the ability and political willpower to ween their economies from overdependence on rather insecure sources of supply.

OIL PRICE SCENARIOS

On the basis of various combinations of world oil demand and supply assumptions from tables 20 and 21, the Energy Information Agency produced 13 alternative projections of world oil prices (see scenarios A through M in appendix I).

World oil prices are determined as the minimum prices of oil needed to clear the world market given alternative estimates of oil demand, supply, and OPEC potential. All prices were expressed in real 1978 dollars per barrel delivered to the east coast of the United States.

The analysis was completed with the use of the oil market simulation (OMS) model, a reduced form version of the larger Data Resources, Inc. (DRI) macroeconomic model, and two energy models, the international energy evaluation system (IEES), and the EIA midterm energy market model. OMS uses a representation of oil supply and demand curves for each region to produce market clearing oil prices.[2]

The results are presented in figures 15 through 17. Figure 15 summarizes the results of those scenarios, which include the high demand growth assumptions (scenarios B, D, G, H, and M). Under these high demand assumptions, oil prices are seen to be most sensitive to the level of free world oil supply potential. Using the low supply assumptions (scenarios G and H), world oil prices were estimated to increase to $28–$31.50 per barrel by 1990 depending upon the level of trade with the Communist countries. However, under the high supply assumptions (scenarios B, D, and M), 1990 prices are projected to increase to only $17.50–$19 per barrel.

Figure 16 summarizes the oil price forecasts under the low demand assumptions (scenarios A, C, E, F, and L). Under those demand assumptions, only those scenarios which assumed low supply (senarios A, C, and L) resulted in any price increase by 1990. In the three low supply cases, 1990 prices were estimated to vary between $22.50 and $23 per barrel depending upon the level of Communist trade. The high free world oil supply cases (E and F) resulted in no price increases over the forecast period.

Figure 17 summarizes the price projections using the low-low demand assumptions (scenarios I, J, and K) through 1985. Again, prices were estimated to increase only under the low supply assumptions, with price increases to $20–$22 per barrel by 1990. Scenario K assumed high oil supplies in the free world and resulted in level prices over the forecast period.

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[2] Documentation of the OMS model appears in appendix II, "An Evaluation of Future World Oil Prices."

FIGURE 15.—Projected World Oil Prices: High Demands

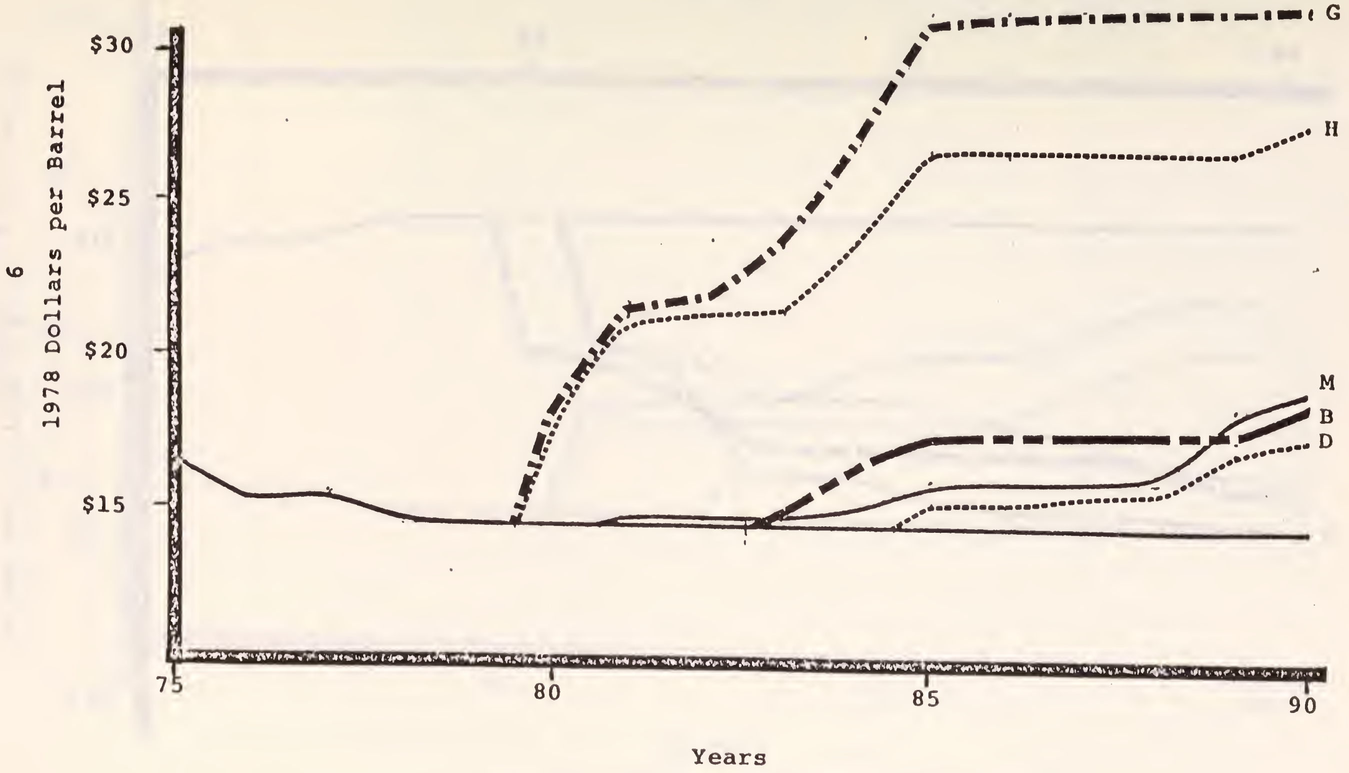


FIGURE 16.—Projected World Oil Prices: Low Demands

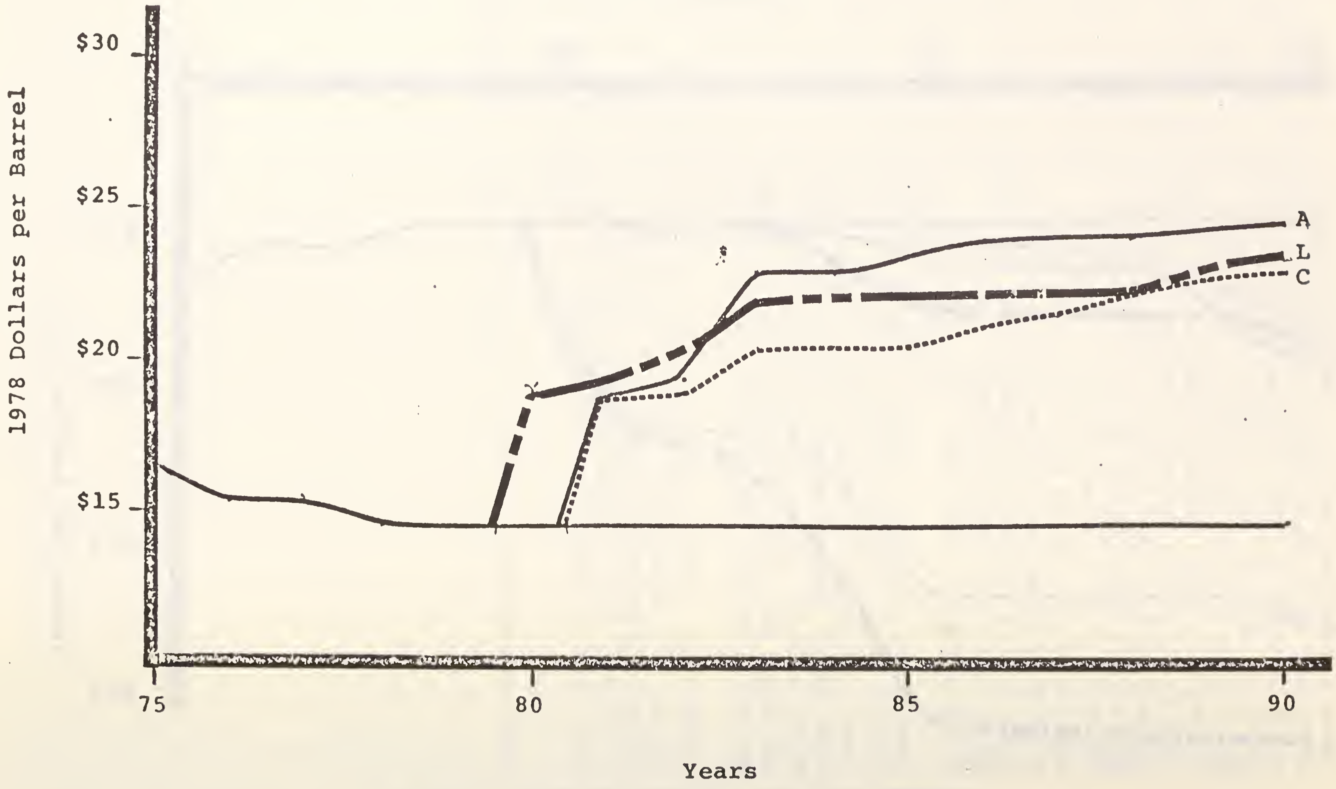
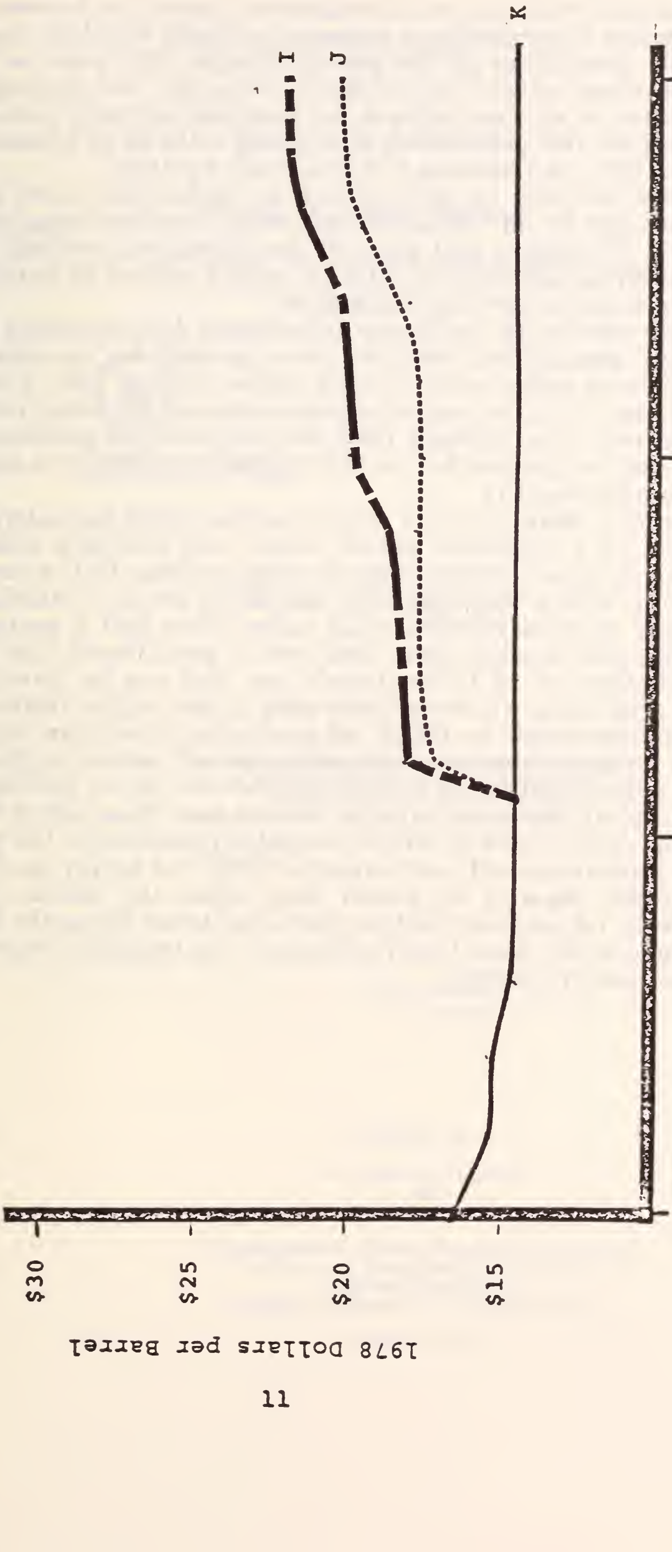


FIGURE 17.—Projected World Oil Prices: Low-Low Demands



While actual world oil price development cannot be foreseen, the above exercise of combining a range of probable world oil demand and supply possibilities for the period through 1990, provides some interesting observations. Out of the 13 scenarios, two projected no price increase at all; two indicate the potential for steep price rises; and eight show real prices rising from today's $14.50 to between $15 and $23 in 1985, and between $17.50 and $24 by 1990.

The price increases (in 1978 dollars) are higher than most recent energy forecasts by oil companies and other, nonprofit organizations (PIRINC). We suggest that much of the difference in outlook is due to the underlying assumptions of OPEC supply and net oil imports by centrally planned economics of OPEC oil.

A similar exercise by the Energy Information Administration based on different assumptions than the ones provided for the above 13 scenarios, shows wider world oil price ranges through 1990. Like the above exercise, the price range includes scenarios projecting no price increase in real terms through 1990, but also includes scenarios estimating a world oil price of $44 (in 1978 dollars) by 1990. For a detailed analysis, see appendix II.

In summary, there is a little doubt that the world has entered the early phase of a transition period, which will gradually shift our dependence on oil to a variety of other energy systems. In the past, the completion of such a transition from one energy source to another (or to a variety of other resources) has taken about half a century. A number of recent studies show that even if post World War II oil reserve additions of 20 billion barrels per year can be maintained, world oil production will most likely peak in the middle 1990's. This assumes no constraints on OPEC oil production other than technical ability to produce from reserves and projected reserve additions of about 10 million barrels per year. Key producers in the Middle East with low capital obsorptive capacity control more than half of OPEC oil reserves. Their desire to stretch available resources for the benefit of future generations will limit available OPEC oil supply, and cause OPEC surplus capacity to vanish long before the middle 1990's. Consequently, oil prices are likely to rise in real terms during the 1980's, forcing—and at the same time facilitating—the transition away from oil to other energy sources.

APPENDIXES

Appendixes I and II

World Oil Price Forecast

APPENDIX I

Department of Energy
Washington, D.C. 20461

ANALYSIS MEMORANDUM
No. AM/IA/78-21

AN EXAMINATION OF SEVERAL WORLD OIL PRICE SCENARIOS GIVEN EXOGENOUS SUPPLY AND DEMAND ESTIMATES

CRN 780830-00378
AAR-MN

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Office of Integrative Analysis
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Energy Information Administration

July 31, 1978

AN EXAMINATION OF SEVERAL WORLD OIL PRICE SCENARIOS GIVEN EXOGENOUS SUPPLY AND DEMAND ESTIMATES

Disclaimer

The energy projections contained in this Analysis Memorandum were produced by EIA at the request of the Department of Energy, International Affairs. EIA has checked to insure that the systems used to make these projections have executed properly, but has not analyzed the results obtained and does not endorse their reasonableness.

I. EXECUTIVE SUMMARY

This paper documents an analysis of future world oil prices completed at the request of the Office of International Affairs (IA), Department of Energy. The analysis is based upon estimates of world oil supply and demand provided by DR. HERMAN FRANSSEN FOR the Senate Energy and Natural Resources Committee and uses the latest EIA price, income, and economic feedback[1/] elasticities to forecast market clearing world oil prices for a number of different scenarios. The assumptions critical to the analysis are:

- The specification of the base supply and demand paths provided ~~by~~ FOR the Senate Committee;
- The OPEC production limits as specified by DOE/IA; and,
- The EIA elasticity estimates which were derived from previous simulations of the PIES, IEES, and DRI macroeconomic models.

The scenario specifications are summarized in Table 1 where the assumptions relating to demand, supply, and Centrally Planned Economies (CPE) net oil imports are outlined. The source of the supply, demand and production estimates is the attached memorandum from International Affairs (IA).

1/ The feedback elasticity is defined to be the expected percent change in economic activity associated with a one percent increase in the world oil price.

Table 1

Scenario Assumptions

Scenario	Demand 1/	Supply 2/	Net Communist Imports 3/
A	Low	Low	High
B	High	High	High
C	Low	Low	Low
D	High	High	Low
E	Low	High	High
F	Low	High	Low
G	High	Low	High
H	High	Low	Low
I	Low-Low	Low	High
J	Low-Low	Low	Low
K	Low-Low	High	Mid
L	Low	Low	Mid
M	High	High	Mid

1/ Refers to Table "World Oil Demand, 1977-90" in attached memorandum from International Affairs.

2/ Refers to Tables "Non-OPEC Supply (million b/d) and "Available OPEC Projection, 1977-90" in the attached memorandum from International Affairs.

3/ "High" refers to net oil imports by 1985 of 2.5 MMB/D, "Low" refers to zero net imports, and "Mid" refers to net oil imports of 1.0 MMB/D by 1985.

The results of the analysis are summarized in Table 2 which shows the market clearing world oil prices expressed in real 1978 dollars per barrel in 1985 and 1990, the reduction in real GNP, and the year of the initial price increase. The analysis indicates that:

- For a mid-range case in terms of assumptions, Case L shows prices increasing in 1980 and rising to $22.00 per barrel in 1985 and $23.00 per barrel in 1990;
- The lowest price increase cases (E, F, and K), which all show no price increase, assume low or low-low demands and high supplies; and,
- The highest price scenario (case G), which assumes high demands, low supplies, and high net communist imports, shows prices increasing in 1980 and rising to a level of $31.50 per barrel by 1985 and then remaining level to 1990.

This analysis contrasts with other recent projections made by EIA[2/] where world oil prices were found to range between $14.50 and $21 per barrel by 1985 and to between $16 and $44 per barrel by 1990 depending upon the economic growth rate, level of OPEC production, and the feedback elasticity assumption. The principal difference between the analysis presented here and that completed previously by EIA are:

- The use of different world oil demands with DR. FRANSSEN ~~the Senate Committee~~ providing significantly lower oil demand than those projected by EIA;
- The use of somewhat different non-OPEC oil supply forecasts; and,

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[2/] See EIA Analysis Memorandum AM/IA-7805, "An Evaluation of Future World Oil Prices."

Table 2

World Oil Price and Economic Impacts
(1978 $'s/barrel)

Scenario	Year of Initial Price Increase	World Oil Price[1/] 1985	World Oil Price[1/] 1990	Percent[2/] U.S. Economic Impac 1985	Percent[2/] U.S. Economic Impac 1990
A	1980	23.00	24.00	1.9	0.4
B	1983	17.50	18.50	1.2	0.5
C	1980	20.00	22.50	1.4	0.3
D	1985	15.00	17.50	0.1	0.7
E	-	14.50	14.50	0.0	0.0
F	-	14.50	14.50	0.0	0.0
G	1980	31.50	31.50	3.1	0.5
H	1980	27.00	28.00	2.5	0.4
I	1981	20.00	22.00	1.7	0.3
J	1981	18.00	20.00	1.0	0.2
K	-	14.50	14.50	0.0	0.0
L	1980	22.00	23.00	1.7	0.3
M	1981	16.00	19.00	0.5	0.2

1/ Prices are stated in 1978 dollars per barrel, C.I.F East Coast of the United States.

2/ Economic impacts are stated as percent reduction in economic activity (real GNP).

- The use of substantially lower near term OPEC production constraints which reflect purely political considerations on the part of certain OPEC governments.

It must be stressed that the results of this analysis are considered to be preliminary in that certain potentially significant issues have not yet been fully addressed by EIA. Some of these issues include:

- Possible unforeseen and radical responses of consumers to very high oil prices;
- The potential for drastic new policy measures when faced with large price increases; and,
- Advanced technological responses.

Therefore, the results presented in this paper should be viewed as only an indication of possible price trends based upon our understanding of the current world energy market. These price forecasts should not be viewed as an exact representation of the energy market in the 1980's.

II. INTRODUCTION

The purpose of this analysis is to estimate world oil prices given certain assumptions regarding:

- World oil demands for three alternative cases;
- Non-OPEC oil supply estimates for two alternative cases;
- OPEC production estimates for two alternative cases; and,
- Net Communist oil import estimates for three alternative cases.

Various combinations of these assumptions are used to produce a total of 13 alternative projections of world oil prices. World oil prices are determined as the minimum prices of oil needed to clear the world market given alternative estimates of oil demand, supply, and OPEC production potential. All prices are expressed in real 1978 dollars per barrel delivered to the East Coast of the United States.

The analysis was completed with the use of the Oil Market Simulation (OMS) model, a reduced form version of the larger Data Resources, Inc. (DRI) macroeconomic model and two energy models, the International Energy Evaluation System (IEES), and the EIA Mid Term Energy Market Model. OMS uses a representation of oil supply and demand curves for each region to produce market clearing oil prices. Complete documentation of the model appears in Appendix B of Analysis Memorandum AM/IA-7803, "An Evaluation of Future World Oil Prices".

In all scenarios, the 35 percent carry-forward, low foreign feedback elasticities from Analysis Memorandum No. AM/IA-7805 are assumed. This assumption produces an upper bound on possible prices; however, in the cases simulated here, the prices that would result from the alternative feedback elasticity assumptions would differ only slightly (less than $5 per barrel for the highest price scenario and proportionately less for the other scenarios).

It should be noted that the analysis presented in this paper is based upon the demand and supply paths provided in the attached memorandum from the Office of International Affairs. Therefore, since the resulting price forecasts depend critically upon these assumptions, they will not necessarily agree with other forecasts using the same model but different initial supply and demand projections.

III. RESULTS

The results of the analysis of the 13 scenarios are presented in Figures 1 through 3. In addition, Appendix A contains the summary computer printouts for each simulation. Figure 1 summarizes the results of those scenarios which include the high demand growth assumptions (scenarios B, D, G, H, and M). Under these high demand assumptions, oil prices are seen to be most sensitive to the level of Free World oil supply potential. Using the low supply assumptions (scenarios G and H), world oil prices were estimated to increase to $28-$31.50 per barrel by 1990 depending upon the level of trade with the communist countries. However, under the high supply assumptions (scenarios B, D, and M), 1990 prices are projected to increase to only $17.50-$19 per barrel.

Figure 2 summarizes the oil price forecasts under the low demand assumptions (scenarios A, C, E, F, and L). Under those demand assumptions, only those scenarios which assumed low supply (scenarios A, C, and L) resulted in any price increase by 1990. In the three low supply cases, 1990 prices were estimated to vary between $22.50 and $23 per barrel depending upon the level of communist trade. The high Free World oil supply cases (E and F), resulted in no price increases over the forecast period.

Figure 3 summarizes the price projections using the low-low demand assumptions (scenarios I, J, and K). Again, prices were estimated to increase only under the low supply assumptions

Figure 1

Projected World Oil Prices:
High Demands

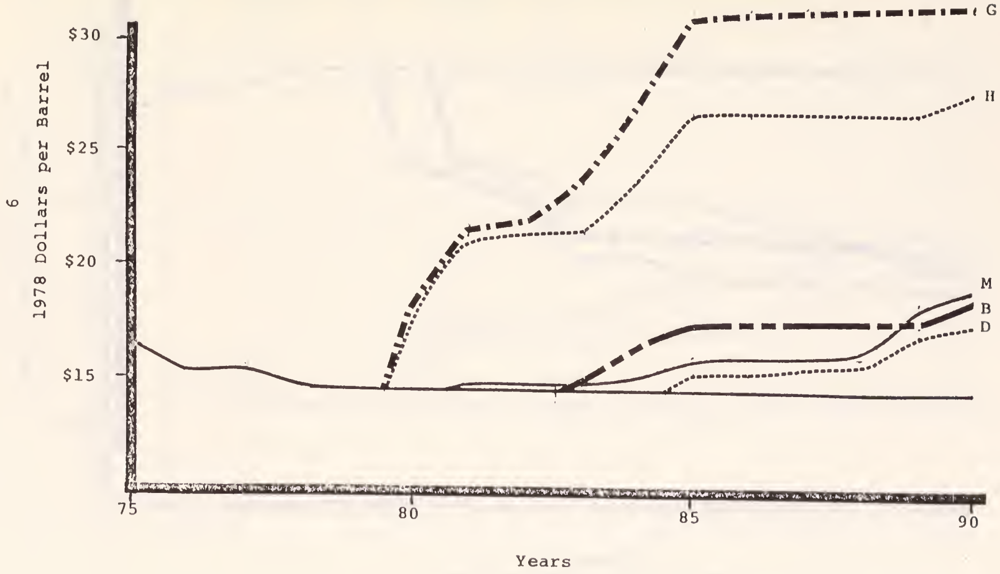


Figure 2
Projected World Oil Prices:
Low Demands

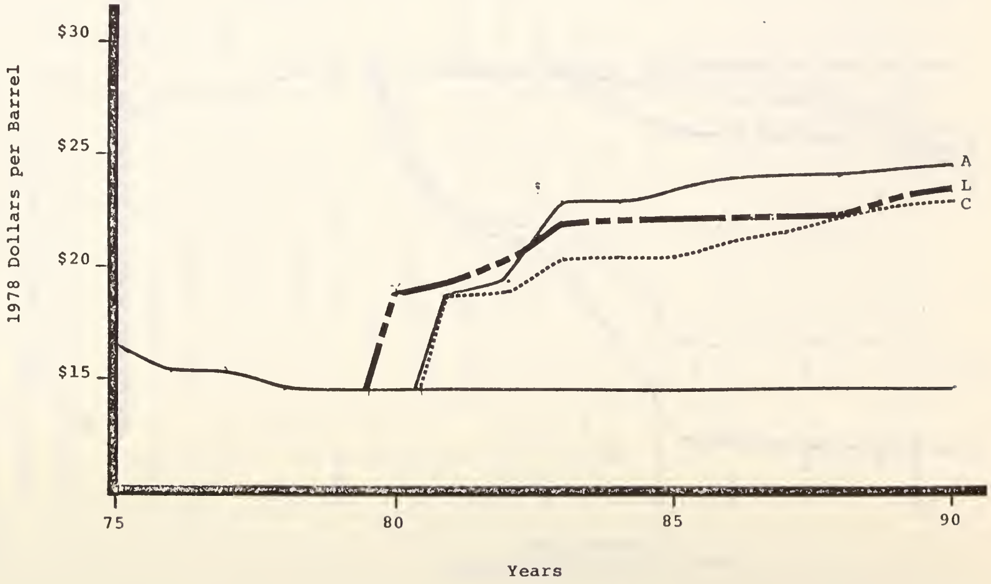


Figure 3

Projected World Oil Prices:
Low-Low Demands

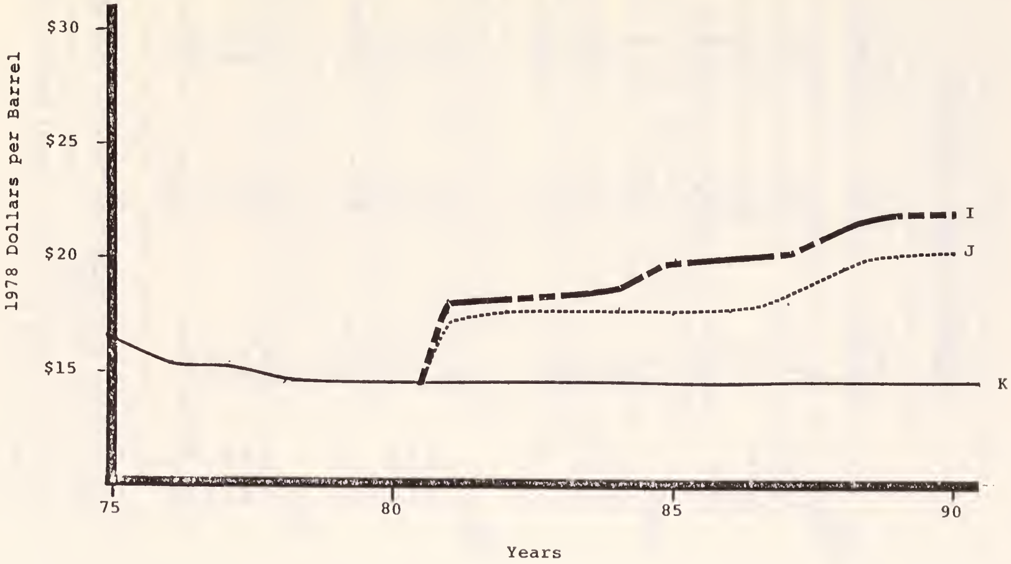


Table 3

Comparison of EIA and IA Oil Demand and Supply Projections

	IA 1/ Low-Low	IA 1/ Low	EIA 2/ Series C	IA 1/ High
1985				
Demand				
U.S.	19.5	19.6	21.2	22.8
Canada	2.6	2.7	2.4	2.5
Japan	7.1	8.6	8.4	8.6
Europe	15.4	16.5	17.3	18.3
LDC	11.0	12.5	13.2	12.5
OPEC	3.5	3.6	3.4	3.6
Total	59.1	63.4	65.9	68.4
Supply				
U.S.	N/A	9.5	10.2	10.9
Canada	N/A	1.5	1.3	1.9
Japan	N/A	0	0.01	0
Europe	N/A	3.7	4.5	4.8
LDC	N/A	5.9	7.7	9.5
CPE (Net)	N/A	-2.5	-2.5	0
Total		18.1	21.2	27.1
1990				
Demand				
U.S.	21.2	22.3	23.5	24.5
Canada	3.1	3.2	2.8	3.2
Japan	8.5	9.5	11.5	10.5
Europe	17.1	18.0	22.5	19.0
LDC	12.7	14.0	17.8	15.4
OPEC	4.6	4.8	4.7	5.6
Total	67.2	71.8	82.9	78.2
Supply				
U.S.	N/A	10.1	9.8	11.4
Canada	N/A	1.4	1.3	1.9
Japan	N/A	0	0.01	0
Europe	N/A	4.0	5.0	5.1
LDC	N/A	7.9	8.3	12.4
CPE (Net)	N/A	-2.5	-2.5	0
Total		20.9	21.9	30.8

1/ From attached memorandum from International Affairs, "Data for the OMS Runs"

2/ From the EIA Administrator's Annual Report, Volume II, 1977, Projection Series C.

with prices increasing to $20-$22 per barrel by 1990. Scenario K assumed high oil supplies in the Free World and resulted in level prices over the forecast period.

As mentioned above, the results of this analysis differ from earlier EIA analyses due to differences in the underlying demand and supply path assumptions. Table 3 summarizes these differences which include:

- In 1985 the current mid-range EIA forecast of demand is approximately in the center of the high and low cases presented here with the new low-low demands lying 6.8 MMB/D below the EIA Projection Series C demands;
- The mid-range 1985 EIA forecast of non-OPEC supply lies approximately in the center of the high and low non-OPEC supply estimates used here;
- The 1990 high and low demand projections used here are significantly below the EIA Projection Series C demand forecast and the low-low demands are 15.7 MMB/D below the EIA Projection Series C demands;
- The 1990 high non-OPEC supplies used here are significantly higher than the EIA Projection Series C supply forecasts; and,
- The near term OPEC production constraints are significantly lower than those used previously by EIA and they reflect purely political considerations on the part of certain OPEC governments.

Since there is no documentation of the source of the demands and supplies provided by JR. FRANSSEN FOR the Senate Energy and Natural Resources Committee, no conclusions can be offered as to the underlying reasons for these differences.

To conclude, this analysis has shown a range of possible world oil price increases given the underlying demand and supply assumptions. These assumptions are critical to the analysis and represent a different view of possible world oil supply and demand than that forecasted by EIA.

APPENDIX A

DETAILED SCENARIO RESULTS

Notes

The last letter of each scenario name specifies the particular scenario defined in Table 1 of the executive summary. For example, Scenario "IAA" refers to IA scenario "A".

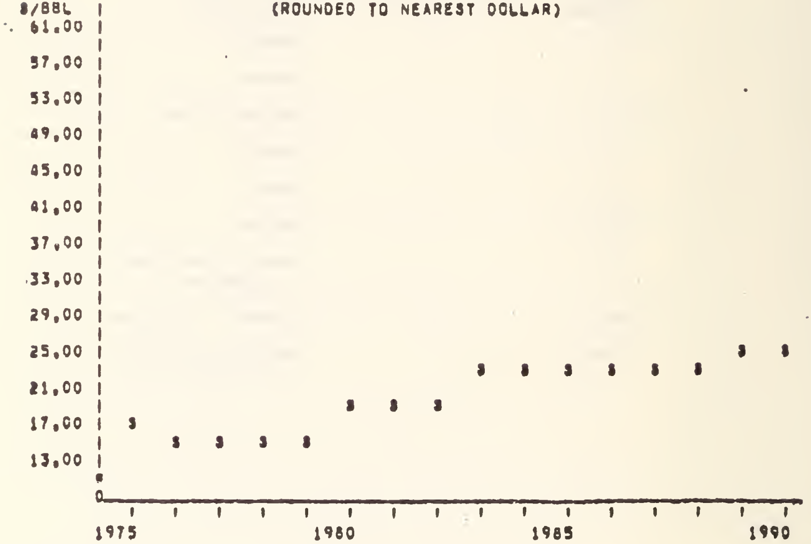
Other symbols used in the attached computer printouts are as follows:

Symbol	Definition
S	Supply
D	Demand
US	United States
CN	Canada
JP	Japan
EU	Europe
LD	Lesser Developed Countries
SL	Synthetic Liquids
CMX	Centrally Planned Economies

SCENARIO: IAA

YEAR	CIF PRICE (78$/BBL)	OPEC PRODUCTION (MMB/D)	U.S. IMPORTS (MMB/D)	PER CENT REDUCTION IN INCOME
1975	16.58	27.13	6.32	0.0
1976	15.32	31.16	7.06	0.0
1977	15.46	31.75	8.51	0.0
1978	14.50	31.62	8.42	0.0
1979	14.50	33.14	9.05	0.0
1980	18.94	33.40	8.97	0.47
1981	18.94	32.77	7.55	1.21
1982	19.32	33.80	8.05	1.75
1983	22.90	34.00	8.35	2.77
1984	22.90	33.16	6.67	2.38
1985	23.32	34.40	6.73	1.92
1986	23.78	34.40	6.49	1.45
1987	23.78	34.66	6.43	0.99
1988	23.85	35.20	6.50	0.68
1989	24.19	35.60	6.67	0.35
1990	24.20	36.00	6.89	0.35

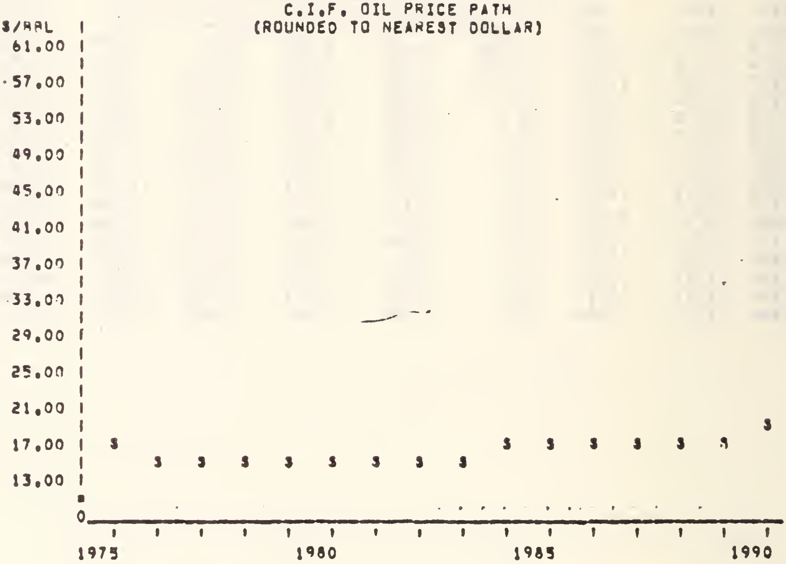
C.I.F. OIL PRICE PATH
(ROUNDED TO NEAREST DOLLAR)



```
                         SCENARIO: IAA

YEAR   DUS       DCN       DJP       DEU       DLD      DOPEC      DWORLD
----   ---       ---       ---       ---       ---      ---        ----
 1975 16.29      1.59      4.57     13.30      6.48      2.04      44.27
 1976 16.79      1.69      5.23     14.10      8.92      2.18      48.91
 1977 17.93      1.76      5.38     14.00      8.76      2.32      50.15
 1978 18.92      1.88      5.78     14.31      8.96      2.47      52.32
 1979 19.45      1.99      6.18     14.62      9.47      2.63      54.34
 1980 19.27      2.00      6.22     14.38      9.76      2.78      54.40
 1981 17.45      2.04      6.38     14.21     10.06      2.94      53.07
 1982 18.06      2.12      6.57     14.08     10.36      3.04      54.24
 1983 18.46      2.06      6.54     13.63     10.52      3.25      54.47
 1984 16.89      2.12      6.76     13.59     10.82      3.40      53.58
 1985 17.18      2.20      7.07     13.74     11.22      3.56      54.98
 1986 17.38      2.25      7.26     13.96     11.57      3.80      56.24
 1987 17.75      2.33      7.52     14.29     11.89      4.10      57.88
 1988 18.24      2.42      7.76     14.56     12.31      4.40      59.69
 1989 18.81      2.51      7.98     15.00     12.55      4.60      61.46
 1990 19.54      2.60      8.18     15.32     12.76      4.80      63.19

YEAR     SUS       SCN      SJP       SEU       SLD       SSL      CMX       SWORLD
----     ---       ---      ---       ---       ---       ---      ---       ----
 1975    9.97     1.770    0.010     0.550     3.340     0.0       1.500    17.140
 1976    9.72     1.580    0.010     0.850     4.320     0.0       1.260    17.745
 1977    9.42     1.580    0.010     1.490     5.000     0.000     0.900    18.400
 1978   10.50     1.600    0.0       2.200     4.900     0.400     1.100    20.700
 1979   10.40     1.600    0.0       3.000     5.000     0.400     0.800    21.200
 1980   10.30     1.600    0.0       3.200     5.100     0.400     0.400    21.000
 1981    9.90     1.500    0.0       3.400     5.200     0.400    -0.100    20.300
 1982   10.01     1.532    0.0       3.576     5.517     0.400    -0.600    20.437
 1983   10.11     1.564    0.0       3.753     5.838     0.400    -1.200    20.469
 1984   10.22     1.597    0.0       3.832     6.174     0.400    -1.800    20.423
 1985   10.46     1.651    0.0       4.073     6.494     0.400    -2.500    20.575
 1986   10.89     1.701    0.0       4.197     7.146     0.400    -2.500    21.833
 1987   11.32     1.633    0.0       4.433     7.933     0.400    -2.500    23.214
 1988   11.74     1.677    0.0       4.551     8.623     0.400    -2.500    24.489
 1989   12.14     1.716    0.0       4.781     9.318     0.400    -2.500    25.853
 1990   12.64     1.752    0.0       5.007     9.889     0.400    -2.500    27.191
```

SCENARIO: IAB

YEAR	CIF PRICE (78$/BBL)	OPEC PRODUCTION (MMB/D)	U.S. IMPORTS (MMB/D)	PER CENT REDUCTION IN INCOME
1975	16.58	27.31	6.32	0.0
1976	15.32	31.05	7.06	0.0
1977	15.46	31.75	8.51	0.0
1978	14.50	30.83	8.12	0.0
1979	14.50	31.77	8.51	0.0
1980	14.50	33.57	9.23	0.0
1981	14.50	35.37	9.54	0.0
1982	14.50	35.73	9.82	0.0
1983	14.60	38.20	10.67	0.01
1984	16.50	39.20	11.14	0.59
1985	17.53	40.20	10.93	1.16
1986	17.53	39.49	10.48	1.16
1987	17.53	39.46	10.23	0.99
1988	17.53	40.70	10.39	0.77
1989	17.53	42.39	10.87	0.56
1990	18.52	43.10	11.01	0.49

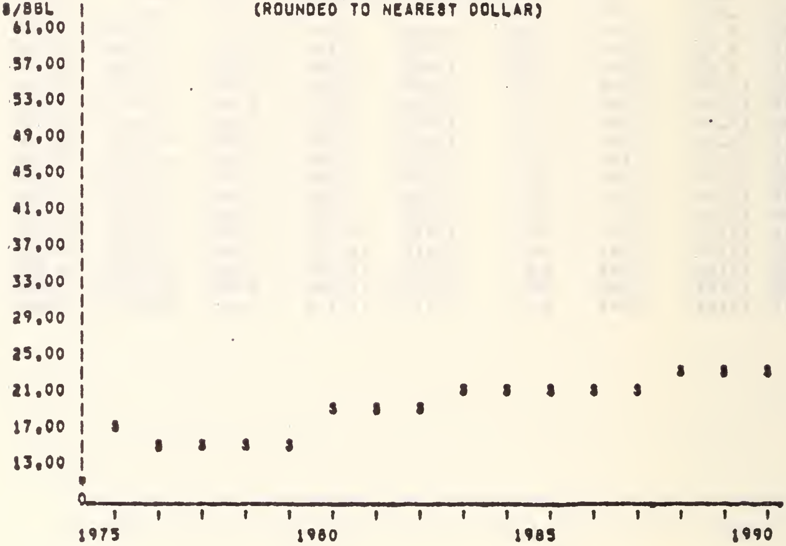

C.I.F. OIL PRICE PATH
(ROUNDED TO NEAREST DOLLAR)

```
                   SCENARIO: IAB

YEAR   DUS        DCN       DJP       DEU       DLD      DOPEC      DWORLD
----   ---        ---       ---       ---       ---       ---       ----
 1975 16.29       1.77      4.57     13.30      6.48      2.00     44.45
 1976 16.79       1.58      5.23     14.10      8.92      2.18     48.80
 1977 17.93       1.76      5.38     14.00      8.76      2.32     50.15
 1978 18.62       1.69      5.78     14.31      8.96      2.47     51.83
 1979 19.11       1.76      6.18     14.62      9.47      2.63     53.77
 1980 19.83       1.88      6.58     14.93      9.97      2.78     55.97
 1981 20.24       1.99      6.98     15.64     10.48      2.94     58.27
 1982 20.52       2.11      7.38     15.55     10.98      3.09     59.63
 1983 21.47       2.23      7.77     16.80     11.48      3.25     63.00
 1984 21.94       2.27      7.91     16.85     11.83      3.40     64.20
 1985 21.84       2.30      8.03     17.36     12.12      3.56     65.22
 1986 21.59       2.39      8.07     17.15     12.29      3.90     65.38
 1987 21.60       2.46      8.24     17.12     12.81      4.20     66.44
 1988 21.99       2.73      8.63     17.31     13.28      4.80     68.75
 1989 22.70       2.83      9.42     17.55     13.69      5.20     71.39
 1990 23.06       2.90      9.73     17.57     14.71      5.60     73.56

YEAR    SUS         SCN       SJP       SEU        SLD       SSL      CMX        SWORLD
----    ---         ---       ---       ---        ---       ---      ---        ----
 1975    9.97      1.770     0.010     0.550      3.340     0.0        1.500     17.140
 1976    9.72      1.580     0.010     0.850      4.320     0.0        1.260     17.745
 1977    9.42      1.580     0.010     1.490      5.000     0.000      0.900     18.400
 1978   10.50      1.600     0.0       2.200      5.200     0.400      1.100     21.000
 1979   10.60      1.700     0.0       3.000      5.500     0.400      0.800     22.000
 1980   10.60      1.700     0.0       3.400      5.900     0.400      0.400     22.400
 1981   10.70      1.800     0.0       3.600      6.500     0.400     -0.100     22.900
 1982   10.70      1.800     0.0       3.900      7.700     0.400     -0.600     23.900
 1983   10.80      1.900     0.0       4.500      8.400     0.400     -1.200     24.800
 1984   10.80      1.900     0.0       4.700      9.000     0.400     -1.800     25.000
 1985   10.91      1.901     0.0       4.803      9.505     0.400     -2.500     25.015
 1986   11.11      1.920     0.0       4.850     10.104     0.400     -2.500     25.889
 1987   11.36      1.945     0.0       5.017     10.751     0.400     -2.500     26.978
 1988   11.60      1.969     0.0       5.180     11.397     0.400     -2.500     28.050
 1989   11.83      1.990     0.0       5.236     12.042     0.400     -2.500     29.000
 1990   12.05      2.009     0.0       5.391     13.108     0.400     -2.500     30.460
```

SCENARIO: IAC

YEAR	CIF PRICE (78$/BBL)	OPEC PRODUCTION (MMB/D)	U.S. IMPORTS (MMB/D)	PER CENT REDUCTION IN INCOME
1975	16.58	27.13	6.32	0.0
1976	15.32	31.16	7.06	0.0
1977	15.46	31.75	8.51	0.0
1978	14.50	31.62	8.42	0.0
1979	14.50	33.14	9.05	0.0
1980	18.94	33.40	8.97	0.47
1981	18.94	32.67	7.55	1.21
1982	18.94	33.39	8.11	1.63
1983	20.41	34.00	8.73	2.08
1984	20.41	33.02	7.17	1.79
1985	20.41	34.12	7.41	1.39
1986	21.02	34.40	7.32	1.09
1987	21.27	34.80	7.34	0.77
1988	22.14	35.20	7.39	0.58
1989	22.44	35.60	7.59	0.30
1990	22.55	36.00	7.83	0.30

C.I.F. OIL PRICE PATH
(ROUNDED TO NEAREST DOLLAR)



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                    SCENARIO: IAC

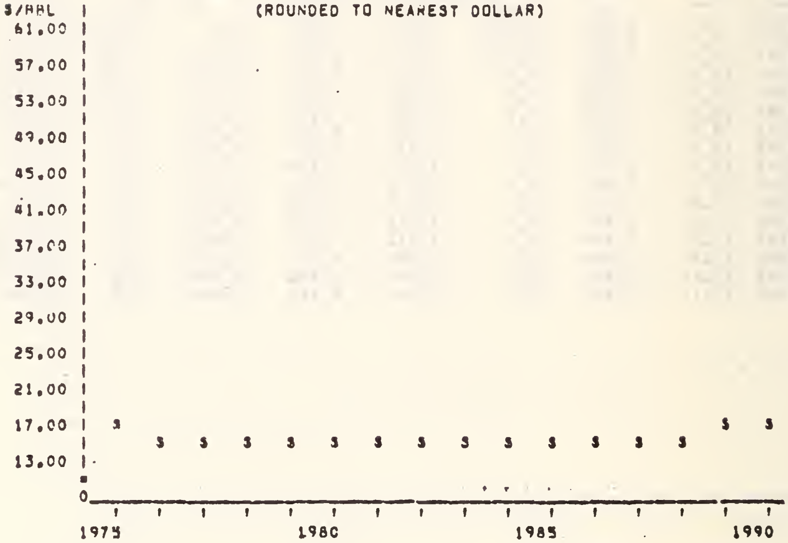
YEAR   DUS        DCN       DJP       DEU       DLD      DOPEC     DWORLD
----   ---        ---       ---       ---       ---       ---       ----
 1975 16.29       1.59      4.57     13.30      6.48      2.04     44.27
 1976 16.79       1.69      5.23     14.10      8.92      2.18     48.91
 1977 17.93       1.76      5.38     14.00      8.76      2.32     50.15
 1978 18.92       1.88      5.78     14.31      8.96      2.47     52.32
 1979 19.45       1.99      6.18     14.62      9.47      2.63     54.34
 1980 19.27       2.00      6.22     14.38      9.76      2.78     54.40
 1981 17.45       2.04      6.38     14.21     10.06      2.94     53.07
 1982 18.12       2.13      6.61     14.14     10.39      3.04     54.43
 1983 18.85       2.13      6.77     14.00     10.68      3.25     55.67
 1984 17.37       2.21      7.07     14.10     11.06      3.40     55.21
 1985 17.76       2.32      7.44     14.37     11.52      3.56     56.96
 1986 18.00       2.38      7.60     14.62     11.89      3.80     58.29
 1987 18.34       2.46      7.83     14.91     12.19      4.10     59.83
 1988 18.73       2.52      8.00     15.08     12.56      4.40     61.28
 1989 19.24       2.60      8.19     15.45     12.77      4.60     62.85
 1990 19.94       2.68      8.36     15.72     12.96      4.80     64.46

YEAR    SUS         SCN      SJP       SEU       SLD       SSL     CMX        SWORLD
----    ---         ---      ---       ---       ---       ---     ---        ----
 1975    9.97      1.770    0.010     0.550     3.340     0.0       1.500    17.140
 1976    9.72      1.580    0.010     0.850     4.320     0.0       1.260    17.745
 1977    9.42      1.580    0.010     1.490     5.000     0.000     0.900    18.400
 1978   10.50      1.600    0.0       2.200     4.900     0.400     1.100    20.700
 1979   10.40      1.600    0.0       3.000     5.000     0.400     0.800    21.200
 1980   10.30      1.600    0.0       3.200     5.100     0.400     0.400    21.000
 1981    9.90      1.500    0.0       3.400     5.200     0.400     0.0      20.400
 1982   10.01      1.532    0.0       3.576     5.517     0.400     0.0      21.037
 1983   10.11      1.564    0.0       3.753     5.838     0.400     0.0      21.669
 1984   10.20      1.594    0.0       3.826     6.165     0.400     0.0      22.189
 1985   10.35      1.634    0.0       4.029     6.425     0.400     0.0      22.834
 1986   10.68      1.670    0.0       4.118     7.012     0.400     0.0      23.884
 1987   11.01      1.589    0.0       4.312     7.717     0.400     0.0      25.025
 1988   11.34      1.620    0.0       4.396     8.329     0.400     0.0      26.082
 1989   11.66      1.649    0.0       4.593     8.950     0.400     0.0      27.249
 1990   12.11      1.679    0.0       4.797     9.474     0.400     0.0      28.461
```

SCENARIO: IAD

YEAR	CIF PRICE (78$/BBL)	OPEC PRODUCTION (MMB/D)	U.S. IMPORTS (MMB/D)	PER CENT REDUCTION IN INCOME
1975	16.58	27.31	6.32	0.0
1976	15.32	31.05	7.06	0.0
1977	15.46	31.75	8.51	0.0
1978	14.50	30.83	8.12	0.0
1979	14.50	31.77	8.51	0.0
1980	14.50	33.57	9.23	0.0
1981	14.50	35.27	9.54	0.0
1982	14.50	35.13	9.82	0.0
1983	14.50	37.06	10.69	0.0
1984	14.50	38.76	11.57	0.0
1985	15.29	40.20	11.71	0.10
1986	15.29	40.26	11.53	0.24
1987	15.29	40.59	11.41	0.33
1988	15.34	42.00	11.63	0.35
1989	17.14	42.50	11.78	0.88
1990	17.41	43.10	11.91	0.74

C.I.F. OIL PRICE PATH
(ROUNDED TO NEAREST DOLLAR)



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                    SCENARIO: IAO

YEAR   DUS        DCN       DJP       DEU       DLD      DOPEC     DWORLD
----   ---        ---       ---       ---       ---      ---       ----
 1975 16.29       1.77      4.57     13.30      6.48     2.04      44.45
 1976 16.77       1.58      5.23     14.10      8.92     2.18      48.60
 1977 17.93       1.76      5.38     14.00      8.76     2.32      50.15
 1978 18.62       1.69      5.78     14.31      8.96     2.47      51.83
 1979 19.11       1.76      6.18     14.62      9.47     2.63      53.77
 1980 19.93       1.88      6.58     14.93      9.97     2.78      55.97
 1981 20.24       1.99      6.98     15.64     10.48     2.94      58.27
 1982 20.52       2.11      7.38     15.55     10.98     3.09      59.63
 1983 21.49       2.23      7.78     16.82     11.49     3.25      63.06
 1984 22.37       2.35      8.18     17.27     11.99     3.40      65.56
 1985 22.61       2.43      8.48     18.17     12.45     3.56      67.70
 1986 22.53       2.55      8.55     18.14     12.70     3.90      68.36
 1987 22.56       2.63      8.72     18.14     13.25     4.20      69.50
 1988 22.91       2.92      9.09     18.28     13.72     4.80      71.72
 1989 23.20       2.92      9.59     18.07     13.93     5.20      72.92
 1990 23.46       2.97      9.86     17.95     14.89     5.60      74.72

YEAR     SUS        SCN      SJP       SEU       SLD      SSL     CMX       SWORLD
----     ---        ---      ---       ---       ---      ---     ---       ----
 1975     9.97     1.770    0.010     0.550     3.340    0.0       1.500    17.140
 1976     9.72     1.580    0.010     0.850     4.320    0.0       1.260    17.745
 1977     9.42     1.540    0.010     1.490     5.000    0.000     0.900    18.400
 1978    10.50     1.600    0.0       2.200     5.200    0.400     1.100    21.000
 1979    10.60     1.700    0.0       3.000     5.500    0.400     0.800    22.000
 1980    10.60     1.700    0.0       3.400     5.900    0.400     0.400    22.400
 1981    10.70     1.800    0.0       3.600     6.500    0.400     0.0      23.000
 1982    10.70     1.800    0.0       3.900     7.700    0.400     0.0      24.500
 1983    10.80     1.900    0.0       4.500     8.400    0.400     0.0      26.000
 1984    10.80     1.900    0.0       4.700     9.000    0.400     0.0      26.800
 1985    10.90     1.900    0.0       4.800     9.500    0.400     0.0      27.500
 1986    11.00     1.900    0.0       4.800    10.000    0.400     0.0      28.100
 1987    11.14     1.907    0.0       4.919    10.541    0.400     0.0      28.910
 1988    11.28     1.914    0.0       5.037    11.081    0.400     0.0      29.714
 1989    11.42     1.920    0.0       5.053    11.621    0.400     0.0      30.412
 1990    11.55     1.926    0.0       5.169    12.568    0.400     0.0      31.617
```
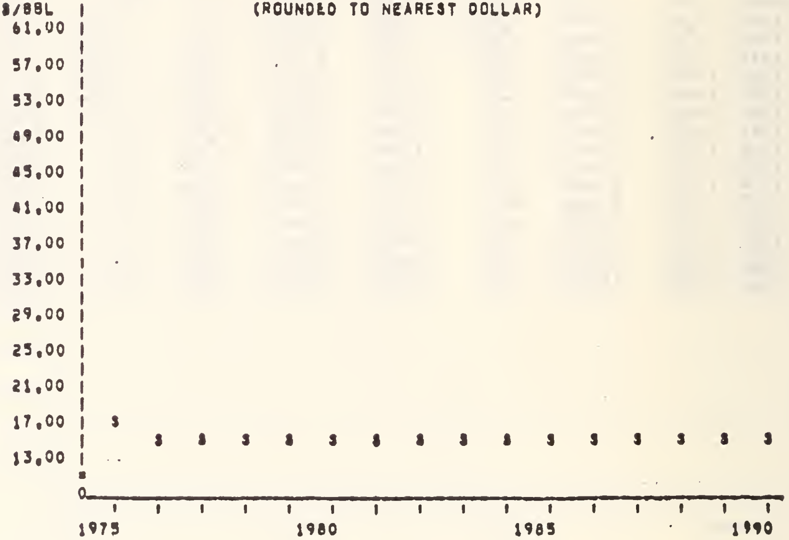

```
                        SCENARIO: IAE

           CIF         OPEC          U.S.       PER CENT
          PRICE     PRODUCTION     IMPORTS     REDUCTION
YEAR    (78$/BBL)     (MMB/D)      (MMB/D)     IN INCOME
----     ------       ------       ------       ------
1975      16.58        27.13         6.32         0.0
1976      15.32        31.16         7.06         0.0
1977      15.46        31.75         8.51         0.0
1978      14.50        31.32         8.42         0.0
1979      14.50        32.34         8.85         0.0
1980      14.50        33.86         9.29         0.0
1981      14.50        33.41         7.74         0.0
1982      14.50        34.95         8.76         0.0
1983      14.50        36.69         9.86         0.0
1984      14.50        36.49         8.38         0.0
1985      14.50        38.40         8.69         0.0
1986      14.50        39.40         9.00         0.0
1987      14.50        40.30         9.30         0.0
1988      14.50        41.30         9.70         0.0
1989      14.50        42.40        10.20         0.0
1990      14.50        43.10        10.90         0.0
```

C.I.F. OIL PRICE PATH
(ROUNDED TO NEAREST DOLLAR)



```
                    SCENARIO: IAE

YEAR  DUS        DCN       DJP        DEU        DLD       DOPEC      DWORLD
----  ---        ---       ---        ---        ---       ---        ----
 1975 16.29      1.59      4.57      13.30       6.48      2.04      44.27
 1976 16.79      1.69      5.23      14.10       8.92      2.18      48.91
 1977 17.93      1.76      5.38      14.00       8.76      2.32      50.15
 1978 18.92      1.88      5.78      14.31       8.96      2.47      52.32
 1979 19.45      1.99      6.18      14.62       9.47      2.63      54.34
 1980 19.89      2.11      6.58      14.93       9.97      2.78      56.26
 1981 18.44      2.23      6.98      15.24      10.48      2.94      56.31
 1982 19.46      2.39      7.38      15.55      10.98      3.09      58.85
 1983 20.66      2.46      7.78      15.85      11.49      3.25      61.49
 1984 19.18      2.58      8.18      16.16      11.99      3.40      61.49
 1985 19.59      2.70      8.58      16.47      12.50      3.56      63.40
 1986 20.00      2.80      8.70      16.80      12.90      3.80      65.00
 1987 20.40      2.90      8.90      17.10      13.20      4.10      66.60
 1988 20.90      3.00      9.10      17.30      13.60      4.40      68.30
 1989 21.50      3.10      9.30      17.70      13.80      4.60      70.00
 1990 22.30      3.20      9.50      18.00      14.00      4.80      71.80

YEAR    SUS        SCN      SJP       SEU        SLD       SSL       CHX      SWORLD
----    ---        ---      ---       ---        ---       ---       ---      ----
 1975    9.97     1.770    0.010     0.550      3.340     0.0        1.500   17.140
 1976    9.72     1.580    0.010     0.850      4.320     0.0        1.260   17.745
 1977    9.42     1.580    0.010     1.490      5.000     0.000      0.900   18.400
 1978   10.50     1.600    0.0       2.200      5.200     0.400      1.100   21.000
 1979   10.60     1.700    0.0       3.000      5.500     0.400      0.800   22.000
 1980   10.60     1.700    0.0       3.400      5.900     0.400      0.400   22.400
 1981   10.70     1.800    0.0       3.600      6.500     0.400     -0.100   22.900
 1982   10.70     1.800    0.0       3.900      7.700     0.400     -0.600   23.900
 1983   10.80     1.900    0.0       4.500      8.400     0.400     -1.200   24.800
 1984   10.80     1.900    0.0       4.700      9.000     0.400     -1.800   25.000
 1985   10.90     1.900    0.0       4.800      9.500     0.400     -2.500   25.000
 1986   11.00     1.900    0.0       4.800     10.000     0.400     -2.500   25.600
 1987   11.10     1.900    0.0       4.900     10.500     0.400     -2.500   26.300
 1988   11.20     1.900    0.0       5.000     11.000     0.400     -2.500   27.000
 1989   11.30     1.900    0.0       5.000     11.500     0.400     -2.500   27.600
 1990   11.40     1.900    0.0       5.100     12.400     0.400     -2.500   28.700
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                    SCENARIO: IAF

YEAR   DUS        DCN      DJP      DEU      DLD      DOPEC     DWORLD
----   ---        ---      ---      ---      ---      ---       ----
 1975 16.29       1.59     4.57     13.30    6.48     2.04     44.27
 1976 16.79       1.69     5.23     14.10    8.92     2.18     48.91
 1977 17.93       1.76     5.38     14.00    8.76     2.32     50.15
 1978 18.92       1.88     5.78     14.31    8.96     2.47     52.32
 1979 19.45       1.99     6.18     14.62    9.47     2.63     54.34
 1980 19.89       2.11     6.58     14.93    9.97     2.78     56.26
 1981 18.44       2.23     6.98     15.24   10.48     2.94     56.31
 1982 19.46       2.39     7.38     15.55   10.98     3.09     58.85
 1983 20.66       2.46     7.78     15.85   11.49     3.25     61.49
 1984 19.18       2.58     8.18     16.16   11.99     3.40     61.49
 1985 19.59       2.70     8.58     16.47   12.50     3.56     63.40
 1986 20.00       2.80     8.70     16.80   12.90     3.80     65.00
 1987 20.40       2.90     8.90     17.10   13.20     4.10     66.60
 1988 20.90       3.00     9.10     17.30   13.60     4.40     68.30
 1989 21.50       3.10     9.30     17.70   13.80     4.60     70.00
 1990 22.30       3.20     9.50     18.00   14.00     4.80     71.80

YEAR     SUS        SCN     SJP      SEU        SLD      SSL     CMX       SWORLD
----     ---        ---     ---      ---        ---      ---     ---       ----
 1975    9.97     1.770    0.010    0.550     3.340    0.0      1.500    17.140
 1976    9.72     1.580    0.010    0.850     4.320    0.0      1.260    17.745
 1977    9.42     1.580    0.010    1.490     5.000    0.000    0.900    18.400
 1978   10.50     1.600    0.0      2.200     5.200    0.400    1.100    21.000
 1979   10.60     1.700    0.0      3.000     5.500    0.400    0.800    22.000
 1980   10.60     1.700    0.0      3.400     5.900    0.400    0.400    22.400
 1981   10.70     1.800    0.0      3.600     6.500    0.400    0.0      23.000
 1982   10.70     1.800    0.0      3.900     7.700    0.400    0.0      24.500
 1983   10.80     1.900    0.0      4.500     8.400    0.400    0.0      26.000
 1984   10.80     1.900    0.0      4.700     9.000    0.400    0.0      26.800
 1985   10.90     1.900    0.0      4.800     9.500    0.400    0.0      27.500
 1986   11.00     1.900    0.0      4.800    10.000    0.400    0.0      28.100
 1987   11.10     1.900    0.0      4.900    10.500    0.400    0.0      28.800
 1988   11.20     1.900    0.0      5.000    11.000    0.400    0.0      29.500
 1989   11.30     1.900    0.0      5.000    11.500    0.400    0.0      30.100
 1990   11.40     1.900    0.0      5.100    12.400    0.400    0.0      31.200
```
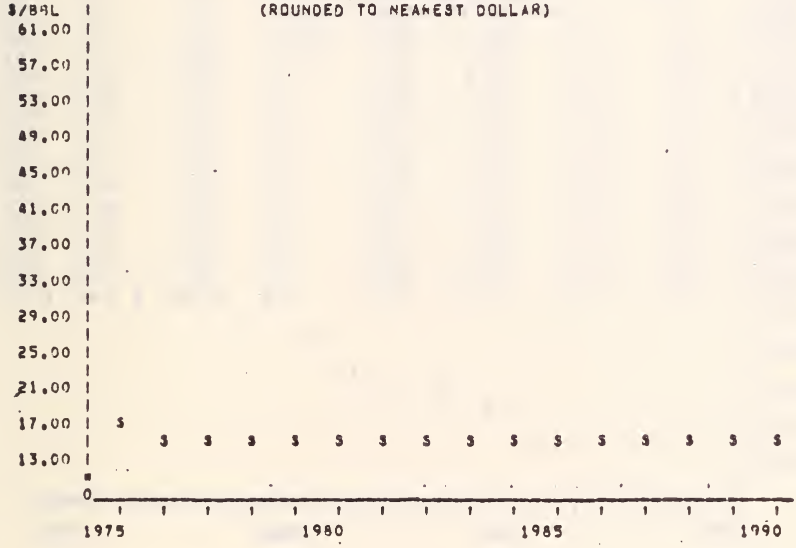

SCENARIO: IAF

YEAR	CIF PRICE (78$/BBL)	OPEC PRODUCTION (MMB/D)	U.S. IMPORTS (MMB/D)	PER CENT REDUCTION IN INCOME
1975	16.58	27.13	6.32	0.0
1976	15.32	31.16	7.06	0.0
1977	15.46	31.75	8.51	0.0
1978	14.50	31.32	8.42	0.0
1979	14.50	32.34	8.85	0.0
1980	14.50	33.86	9.29	0.0
1981	14.50	33.31	7.74	0.0
1982	14.50	34.35	8.76	0.0
1983	14.50	35.49	9.86	0.0
1984	14.50	34.69	8.38	0.0
1985	14.50	35.90	8.69	0.0
1986	14.50	36.90	9.00	0.0
1987	14.50	37.80	9.30	0.0
1988	14.50	38.80	9.70	0.0
1989	14.50	39.90	10.20	0.0
1990	14.50	40.60	10.90	0.0

C.I.F. OIL PRICE PATH
(ROUNDED TO NEAREST DOLLAR)



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                         SCENARIO: IAG

              CIF           OPEC           U.S.        PER CENT
             PRICE       PRODUCTION      IMPORTS      REDUCTION
YEAR       (78$/BBL)       (MMB/D)       (MMB/D)      IN INCOME
----        -------        -------       -------       -------
1975         16.58          27.31          6.32          0.0
1976         13.32          31.05          7.06          0.0
1977         15.46          31.75          8.51          0.0
1978         14.50          31.13          8.12          0.0
1979         14.50          32.57          8.71          0.0
1980         18.19          33.40          9.01          0.40
1981         21.72          33.60          8.92          1.83
1982         21.72          32.98          8.54          2.46
1983         23.81          34.00          5.63          3.00
1984         26.99          34.20          8.62          3.22
1985         31.43          34.40          8.13          3.11
1986         31.43          33.07          7.21          2.26
1987         31.43          32.44          6.57          1.54
1988         31.43          33.03          6.32          1.05
1989         31.43          33.82          6.38          0.52
1990         31.43          34.47          6.13          0.52
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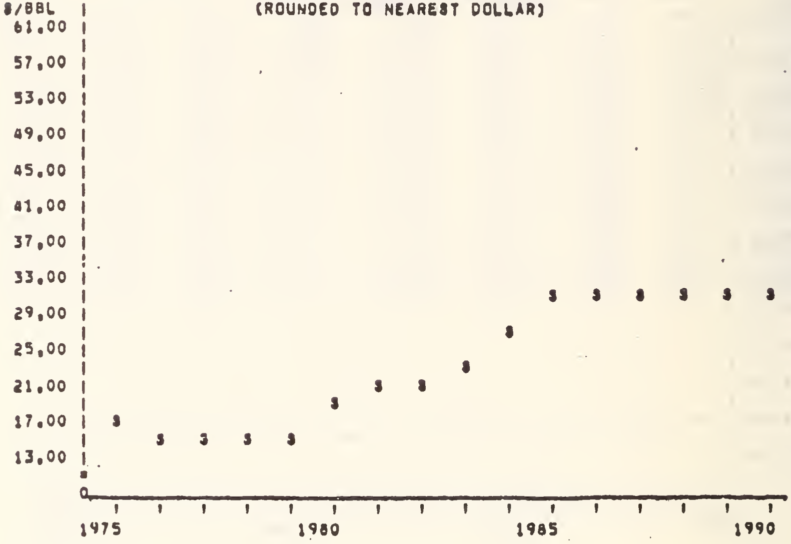
C.I.F. OIL PRICE PATH
(ROUNDED TO NEAREST DOLLAR)



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                      SCENARIO: IAG

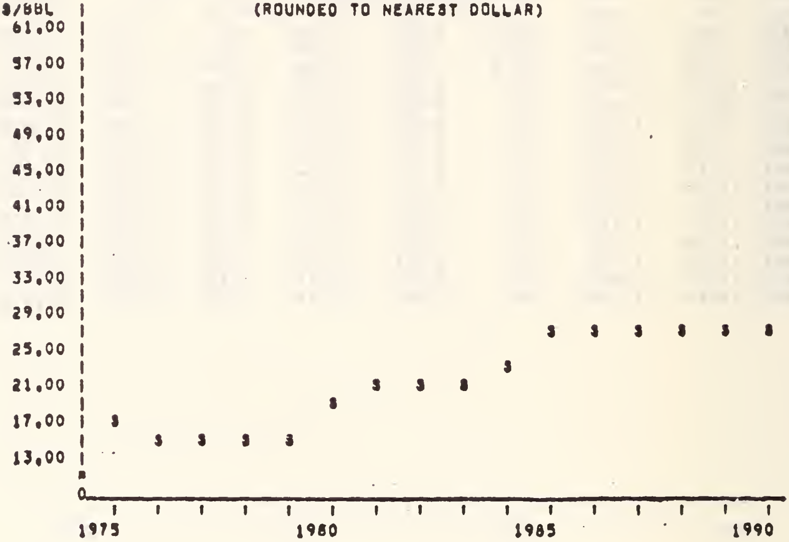
YEAR   DUS        DCN        DJP        DEU        DLO       DOPEC      DWORLD
----   ---        ---        ---        ---        ---        ---        ----
 1975 16.29       1.77       4.57      13.30       6.48       2.04      44.45
 1976 16.79       1.58       5.23      14.10       8.92       2.18      48.80
 1977 17.93       1.76       5.38      14.00       8.76       2.32      50.15
 1978 18.62       1.69       5.78      14.31       8.96       2.47      51.83
 1979 19.11       1.76       6.18      14.62       9.47       2.63      53.77
 1980 19.31       1.79       6.27      14.46       9.79       2.78      54.40
 1981 18.82       1.76       6.18      14.26       9.94       2.94      53.90
 1982 18.51       1.79       6.28      13.58      10.15       3.04      53.35
 1983 18.82       1.81       6.35      14.06      10.35       3.25      54.64
 1984 19.01       1.82       6.40      13.84      10.52       3.40      55.00
 1985 18.79       1.82       6.42      14.11      10.71       3.56      55.41
 1986 18.43       1.86       6.60      13.96      10.90       3.90      55.65
 1987 18.48       1.93       6.86      14.07      11.43       4.20      56.97
 1988 18.88       2.16       7.26      14.35      11.93       4.80      59.37
 1989 19.56       2.25       8.00      14.69      12.37       5.20      62.06
 1990 20.04       2.33       8.36      14.87      13.38       5.60      64.58

YEAR     SUS        SCN       SJP        SEU        SLD        SSL      CMX        SWORLD
----     ---        ---       ---        ---        ---        ---      ---        ----
 1975    9.97     1.770     0.010      0.550      3.340      0.0        1.500     17.140
 1976    9.72     1.580     0.010      0.850      4.320      0.0        1.260     17.745
 1977    9.42     1.580     0.010      1.490      5.000      0.000      0.900     18.400
 1978   10.50     1.600     0.0        2.200      4.900      0.400      1.100     20.700
 1979   10.40     1.600     0.0        3.000      5.000      0.400      0.800     21.200
 1980   10.30     1.600     0.0        3.200      5.100      0.400      0.400     21.000
 1981    9.90     1.500     0.0        3.400      5.200      0.400     -0.100     20.300
 1982    9.98     1.527     0.0        3.564      5.499      0.400     -0.600     20.369
 1983   10.19     1.576     0.0        3.783      5.884      0.400     -1.200     20.636
 1984   10.39     1.624     0.0        3.897      6.279      0.400     -1.800     20.794
 1985   10.66     1.683     0.0        4.151      6.620      0.400     -2.500     21.012
 1986   11.23     1.754     0.0        4.327      7.368      0.400     -2.500     22.577
 1987   11.90     1.718     0.0        4.663      8.345      0.400     -2.500     24.530
 1988   12.55     1.794     0.0        4.868      9.224      0.400     -2.500     26.340
 1989   13.18     1.863     0.0        5.191     10.116      0.400     -2.500     28.247
 1990   13.91     1.928     0.0        5.507     10.877      0.400     -2.500     30.118
```

SCENARIO: IAH

YEAR	CIF PRICE (78$/BBL)	OPEC PRODUCTION (MMB/D)	U.S. IMPORTS (MMB/D)	PER CENT REDUCTION IN INCOME
1975	16.58	27.31	6.32	0.0
1976	15.32	31.05	7.06	0.0
1977	15.46	31.75	8.51	0.0
1978	14.50	31.13	8.12	0.0
1979	14.50	32.57	8.71	0.0
1980	16.19	33.40	9.01	0.40
1981	21.46	33.60	8.95	1.77
1982	21.46	32.54	8.59	2.39
1983	21.46	33.90	8.98	2.38
1984	23.66	34.20	9.21	2.55
1985	26.75	34.40	8.96	2.47
1986	26.75	33.53	8.24	1.79
1987	26.75	33.26	7.76	1.22
1988	26.75	34.20	7.65	0.84
1989	26.75	35.31	7.85	0.42
1990	27.82	36.00	7.64	0.44

C.I.F. OIL PRICE PATH
(ROUNDED TO NEAREST DOLLAR)



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                    SCENARIO: IAM

YEAR   DUS        DCN       DJP      DEU      DLD     DOPEC     DWORLD
----   ---        ---       ---      ---      ---      ---       ----
 1975 16.29       1,77      4.57    13.30     6.48     2.04     44.45
 1976 16.79       1.58      5.23    14.10     8.92     2.18     48.80
 1977 17,93       1,76      5.38    14.00     8.76     2.32     50,15
 1978 18,62       1,69      5,78    14.31     8.96     2.47     51,83
 1979 19.11       1.76      6.18    14.62     9.47     2.63     53.77
 1980 19.31       1.79      6,27    14.46     9,79     2.78     54,40
 1981 18,85       1.77      6.20    14.29     9.95     2,94     54,00
 1982 18.57       1.80      6,31    13.63    10.17     3.04     53.51
 1983 19.17       1.87      6.55    14.40    10,49     3.25     55,72
 1984 19.58       1.91      6.71    14.39    10.76     3.40     56.76
 1985 19.51       1.93      6.81    14.84    11.03     3.56     57.68
 1986 19,25       2.00      6.98    14.75    11.25     3.90     58.12
 1987 19.31       2.07      7.24    14.87    11.81     4.20     59.50
 1958 19,72       2.31      7.65    15.15    12.31     4.80     61.93
 1989 20.41       2.40      8.40    15.47    12.74     5.20     64.62
 1990 20,79       2.47      8,71    15.56    13,74     5.60     66,87

YEAR     SUS        SCN      SJP      SEU      SLD       SSL      CMX       SWORLD
----     ---        ---      ---      ---      ---       ---      ---       ----
 1975    9.97      1,770    0.010    0.550    3.340     0.0       1.500    17,140
 1976    9.72      1.580    0.010    0.850    4.320     0.0       1.260    17,745
 1977    9.42      1.580    0.010    1.490    5,000     0,000     0,900    18.400
 1978   10.50      1.600    0.0      2.200    4.900     0.400     1.100    20,700
 1979   10.40      1.600    0.0      3.000    5.000     0.400     0,800    21,200
 1980   10.30      1.600    0.0      3.200    5.100     0.400     0.400    21.000
 1981    9.90      1.500    0.0      3.400    5.200     0.400     0.0      20.400
 1982    9.95      1.527    0.0      3.564    5.499     0.400     0.0      20.969
 1983   10.18      1.575    0.0      3.779    5.879     0.400     0.0      21,816
 1984   10.37      1.621    0.0      3.890    6,268     0.400     0.0      22.553
 1985   10.55      1.666    0.0      4.110    6.553     0.400     0.0      23.281
 1986   11,01      1.720    0.0      4.243    7,225     0.400     0.0      24.598
 1987   11.55      1,667    0.0      4.524    8.096     0,400     0.0      26.237
 1988   12,06      1.724    0.0      4.678    8.864     0.400     0.0      27.730
 1989   12.56      1.775    0.0      4.946    9.638     0.400     0.0      29.315
 1990   13.15      1.823    0.0      5.208   10.285     0.400     0.0      30.865
```
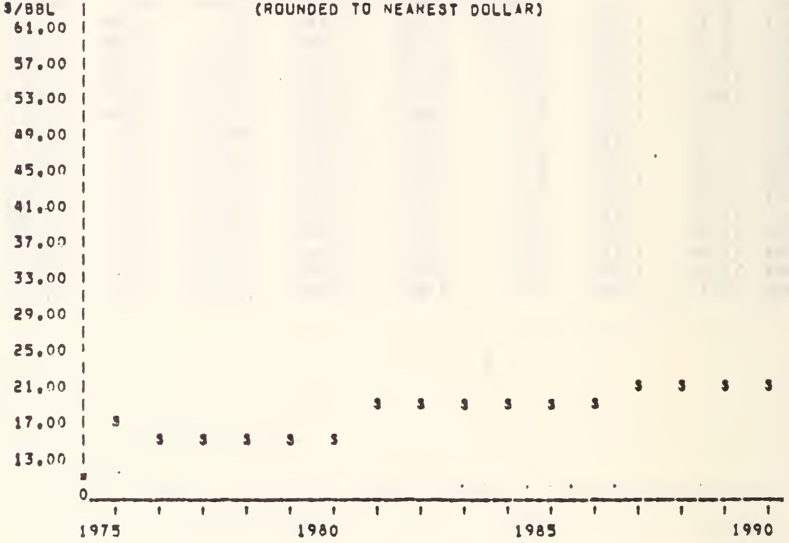

```
                    SCENARIO: IAI

           CIF          OPEC           U.S.       PER CENT
          PRICE      PRODUCTION      IMPORTS     REDUCTION
YEAR    (78$/BBL)     (MMB/D)        (MMB/D)     IN INCOME
----     ------       ------         ------       ------
1975      16.58        27.13           6.32         0.0
1976      15.32        31.16           7.06         0.0
1977      15.46        31.75           8.51         0.0
1978      14.50        31.62           8.42         0.0
1979      14.50        31.50           8.60         0.0
1980      14.50        33.10           8.90         0.0
1981      18.06        33.60           9.00         0.39
1982      18.14        33.80           8.92         1.02
1983      18.14        33.88           8.50         1.37
1984      18.42        34.20           8.16         1.46
1985      19.94        34.40           7.93         1.67
1986      19.94        34.39           7.68         1.29
1987      20.19        34.80           7.61         0.97
1988      21.15        35.20           7.50         0.76
1989      21.75        35.60           7.59         0.55
1990      21.75        36.00           7.52         0.28
```

C.I.F. OIL PRICE PATH
(ROUNDED TO NEAREST DOLLAR)

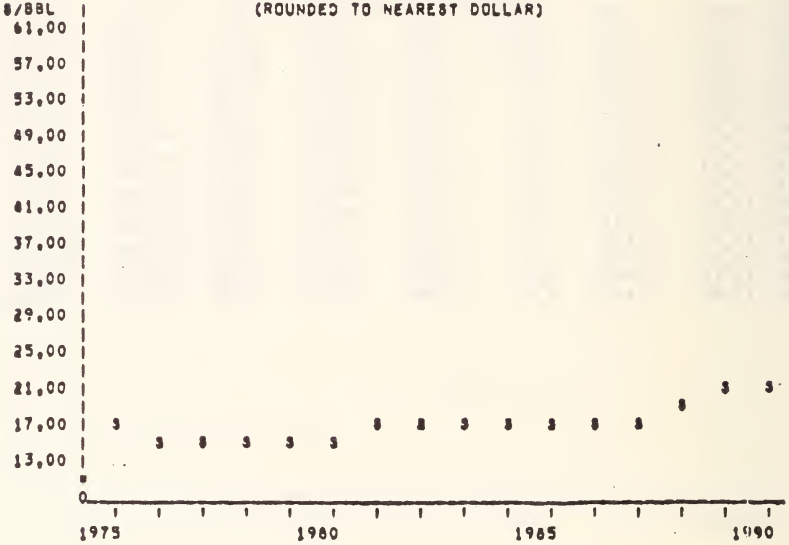


```
                         SCENARIO: IAI

YEAR   DUS         DCN        DJP        DEU        OLD       DOPEC      DWORLD
----   ---         ---        ---        ---        ---        ---        ----
 1975 16.29       1.59       4.57      13.30       6.48       2.04      44.27
 1976 16.79       1.69       5.23      14.10       8.92       2.18      48.91
 1977 17.93       1.76       5.38      14.00       8.76       2.32      50.15
 1978 18.92       1.88       5.78      14.31       8.96       2.47      52.32
 1979 19.00       1.90       5.80      14.40       9.10       2.50      52.70
 1980 19.20       2.10       6.10      14.50       9.50       2.70      54.10
 1981 18.90       2.10       6.01      14.15       9.73       3.00      53.90
 1982 18.72       2.13       6.03      13.86       9.86       3.20      53.80
 1983 18.37       2.18       6.11      13.76      10.02       3.40      53.84
 1984 18.10       2.24       6.22      13.74      10.22       3.50      54.02
 1985 17.93       2.28       6.26      13.73      10.28       3.50      53.98
 1986 17.94       2.25       6.46      13.88      10.61       3.70      54.84
 1987 18.18       2.41       6.75      14.13      10.88       4.00      56.36
 1988 18.37       2.48       7.00      14.44      11.24       4.20      57.73
 1989 18.76       2.54       7.25      14.76      11.51       4.40      59.22
 1990 19.11       2.63       7.54      15.06      11.81       4.60      60.76

YEAR    SUS          SCN      SJP        SEU        SLD        SSL      CMX         SWORLD
----    ---          ---      ---        ---        ---        ---      ---         ----
 1975    9.97      1.770    0.010      0.550      3.340      0.0        1.500     17.140
 1976    9.72      1.580    0.010      0.850      4.320      0.0        1.260     17.745
 1977    9.42      1.580    0.010      1.490      5.000      0.000      0.900     18.400
 1978   10.50      1.600    0.0        2.200      4.900      0.400      1.100     20.700
 1979   10.40      1.600    0.0        3.000      5.000      0.400      0.800     21.200
 1980   10.30      1.600    0.0        3.200      5.100      0.400      0.400     21.000
 1981    9.90      1.500    0.0        3.400      5.200      0.400     -0.100     20.300
 1982    9.80      1.500    0.0        3.500      5.400      0.400     -0.600     20.000
 1983    9.87      1.527    0.0        3.664      5.699      0.400     -1.200     19.961
 1984    9.94      1.553    0.0        3.727      6.004      0.400     -1.800     19.822
 1985   10.00      1.578    0.0        3.893      6.208      0.400     -2.500     19.574
 1986   10.26      1.603    0.0        3.954      6.733      0.400     -2.500     20.451
 1987   10.57      1.526    0.0        4.142      7.412      0.400     -2.500     21.554
 1988   10.87      1.553    0.0        4.216      7.988      0.400     -2.500     22.529
 1989   11.17      1.579    0.0        4.399      8.571      0.400     -2.500     23.614
 1990   11.59      1.607    0.0        4.591      9.067      0.400     -2.500     24.756
```

SCENARIO: IAJ

YEAR	CIF PRICE (78$/BBL)	OPEC PRODUCTION (MMB/D)	U.S. IMPORTS (MMB/D)	PER CENT REDUCTION IN INCOME
1975	16.58	27.13	6.32	0.0
1976	15.32	31.16	7.06	0.0
1977	15.46	31.75	8.51	0.0
1978	14.50	31.62	8.42	0.0
1979	14.50	31.63	8.60	0.0
1980	14.50	33.18	8.90	0.0
1981	17.63	33.60	9.06	0.35
1982	17.63	33.36	9.02	0.89
1983	17.63	33.00	8.65	1.20
1984	17.63	33.02	8.40	1.19
1985	17.63	33.53	8.44	1.03
1986	17.63	34.01	8.36	0.79
1987	17.80	34.80	8.43	0.60
1988	19.45	35.20	8.31	0.59
1989	20.09	35.60	8.42	0.45
1990	20.10	36.00	8.37	0.22

C.I.F. OIL PRICE PATH
(ROUNDED TO NEAREST DOLLAR)



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                         SCENARIO: IAJ

YEAR   DUS        DCN        DJP        DEU        DLD       DOPEC      DWORLD
----   ---        ---        ---        ---        ---       ---        ----
 1975 16,29       1,59       4,57      13,30       6,48       2,04      44,27
 1976 16,79       1,69       5,23      14,10       8,92       2,18      48,91
 1977 17,93       1,76       5,38      14,00       8,76       2,32      50,15
 1978 18,92       1,88       5,78      14,31       8,96       2,47      52,32
 1979 19,00       1,90       5,80      14,40       9,10       2,63      52,83
 1980 19,20       2,10       6,10      14,50       9,50       2,78      54,18
 1981 18,96       2,11       6,04      14,20       9,75       2,94      54,00
 1982 18,02       2,15       6,08      13,96       9,90       3,04      53,96
 1983 18,51       2,21       6,18      13,90      10,08       3,25      54,12
 1984 18,30       2,28       6,33      13,94      10,30       3,40      54,56
 1985 18,38       2,37       6,51      14,18      10,47       3,56      55,47
 1986 18,53       2,37       6,75      14,46      10,86       3,80      56,76
 1987 18,82       2,55       7,05      14,76      11,16       4,10      58,44
 1988 18,91       2,59       7,24      14,99      11,49       4,40      59,62
 1989 19,23       2,64       7,45      15,25      11,73       4,60      60,90
 1990 19,55       2,72       7,73      15,50      12,01       4,80      62,32

YEAR     SUS        SCN      SJP        SEU         SLD        SSL     CMX         SWORLD
----     ---        ---      ---        ---         ---        ---     ---         ----
 1975     9,97     1,770    0,010      0,550       3,340      0,0       1,500     17,140
 1976     9,72     1,580    0,010      0,850       4,320      0,0       1,260     17,745
 1977     9,42     1,580    0,010      1,490       5,000      0,000     0,900     18,400
 1978    10,50     1,600    0,0        2,200       4,900      0,400     1,100     20,700
 1979    10,40     1,600    0,0        3,000       5,000      0,400     0,800     21,200
 1980    10,30     1,600    0,0        3,200       5,100      0,400     0,400     21,000
 1981     9,90     1,500    0,0        3,400       5,200      0,400     0,0       20,400
 1982     9,80     1,500    0,0        3,500       5,400      0,400     0,0       20,600
 1983     9,85     1,524    0,0        3,657       5,688      0,400     0,0       21,122
 1984     9,90     1,546    0,0        3,712       5,980      0,300     0,0       21,535
 1985     9,93     1,568    0,0        3,869       6,169      0,400     0,0       21,940
 1986    10,17     1,588    0,0        3,918       6,671      0,400     0,0       22,744
 1987    10,39     1,499    0,0        4,070       7,283      0,400     0,0       23,640
 1988    10,60     1,514    0,0        4,111       7,789      0,400     0,0       24,415
 1989    10,81     1,529    0,0        4,259       8,300      0,400     0,0       25,300
 1990    11,18     1,550    0,0        4,429       8,748      0,400     0,0       26,312
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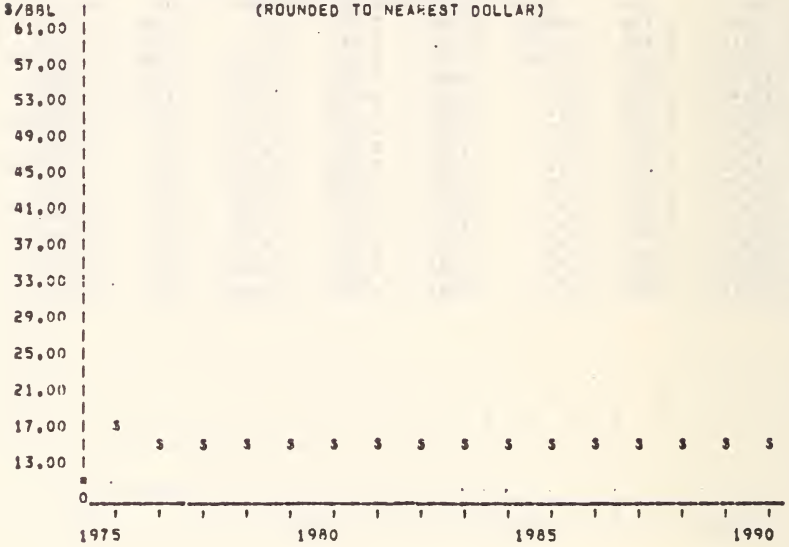
                        SCENARIO: IAK

            CIF          OPEC          U.S.       PER CENT
           PRICE      PRODUCTION     IMPORTS     REDUCTION
YEAR     (78$/BBL)     (MMB/D)       (MMB/D)     IN INCOME
----      ------       ------        ------       ------
1975       16.58        27.13          6.32         0.0
1976       15.32        31.16          7.06         0.0
1977       15.46        31.75          8.51         0.0
1978       14.50        31.32          8.42         0.0
1979       14.50        30.83          8.40         0.0
1980       14.50        31.78          8.60         0.0
1981       14.50        33.34          8.70         0.0
1982       14.50        32.89          8.90         0.0
1983       14.50        32.25          8.70         0.0
1984       14.50        32.30          8.60         0.0
1985       14.50        32.66          8.60         0.0
1986       14.50        33.50          8.70         0.0
1987       14.50        34.50          8.90         0.0
1988       14.50        35.90          9.10         0.0
1989       14.50        37.30          9.50         0.0
1990       14.50        38.00          9.80         0.0
```

C.I.F. OIL PRICE PATH
(ROUNDED TO NEAREST DOLLAR)



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                    SCENARIO: IAK

YEAR   DUS        DCN        DJP        DEU        DLD       DOPEC       DWORLD
----   ---        ---        ---        ---        ---        ---        ----
 1975 16.29       1.59       4.57      13.30       6.48       2.04      44.27
 1976 16.79       1.69       5.23      14.10       8.92       2.18      48.91
 1977 17.93       1.76       5.38      14.00       8.76       2.32      50.15
 1978 18.92       1.88       5.78      14.31       8.96       2.47      52.32
 1979 19.00       1.90       5.80      14.40       9.10       2.63      52.83
 1980 19.20       2.10       6.10      14.50       9.50       2.78      54.18
 1981 19.40       2.20       6.30      14.60       9.90       2.94      55.34
 1982 19.60       2.30       6.50      14.70      10.20       3.09      56.39
 1983 19.50       2.40       6.70      14.90      10.50       3.25      57.25
 1984 19.40       2.50       6.90      15.10      10.80       3.40      58.10
 1985 19.50       2.60       7.10      15.40      11.00       3.56      59.16
 1986 19.70       2.60       7.30      15.70      11.40       3.90      60.60
 1987 20.00       2.80       7.60      16.00      11.70       4.20      62.30
 1988 20.30       2.90       7.90      16.40      12.10       4.80      64.40
 1989 20.80       3.00       8.20      16.80      12.40       5.20      66.40
 1990 21.20       3.10       8.50      17.10      12.70       5.60      68.20

YEAR     SUS         SCN       SJP       SEU         SLD        SSL      CMX        SWORLD
----     ---         ---       ---       ---         ---        ---      ---        ----
 1975    9.97       1.770     0.010     0.550       3.340      0.0       1.500     17.140
 1976    9.72       1.580     0.010     0.850       4.320      0.0       1.260     17.745
 1977    9.42       1.580     0.010     1.490       5.000      0.000     0.900     18.400
 1978   10.50       1.600     0.0       2.200       5.200      0.400     1.100     21.000
 1979   10.60       1.700     0.0       3.000       5.500      0.400     0.800     22.000
 1980   10.60       1.700     0.0       3.400       5.900      0.400     0.400     22.400
 1981   10.70       1.800     0.0       3.600       6.500      0.400    -1.000     22.000
 1982   10.70       1.800     0.0       3.900       7.700      0.400    -1.000     23.500
 1983   10.80       1.900     0.0       4.500       8.400      0.400    -1.000     25.000
 1984   10.80       1.900     0.0       4.700       9.000      0.400    -1.000     25.800
 1985   10.90       1.900     0.0       4.800       9.500      0.400    -1.000     26.500
 1986   11.00       1.900     0.0       4.800      10.000      0.400    -1.000     27.100
 1987   11.10       1.900     0.0       4.900      10.500      0.400    -1.000     27.800
 1988   11.20       1.900     0.0       5.000      11.000      0.400    -1.000     28.500
 1989   11.30       1.900     0.0       5.000      11.500      0.400    -1.000     29.100
 1990   11.40       1.900     0.0       5.100      12.400      0.400    -1.000     30.200
```
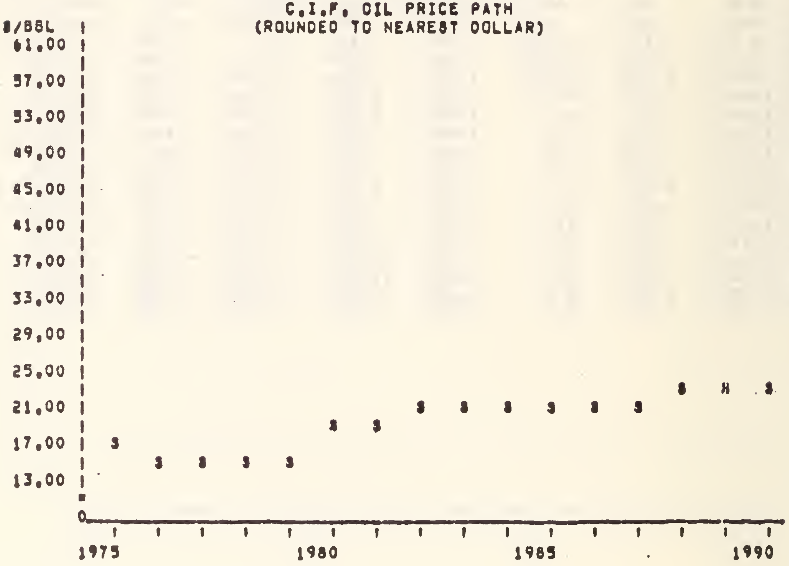

SCENARIO: IAL

YEAR	CIF PRICE (78$/BBL)	OPEC PRODUCTION (MMB/D)	U.S. IMPORTS (MMB/D)	PER CENT REDUCTION IN INCOME
1975	16.58	27.13	6.32	0.0
1976	15.32	31.16	7.06	0.0
1977	15.46	31.75	8.51	0.0
1978	14.50	31.62	8.42	0.0
1979	14.50	33.14	9.05	0.0
1980	18.94	33.40	8.97	0.47
1981	19.10	33.60	7.53	1.25
1982	20.07	33.80	7.92	1.98
1983	21.92	34.00	8.41	2.51
1984	21.92	32.77	6.78	2.15
1985	21.92	33.68	6.95	1.67
1986	21.92	34.06	6.86	1.21
1987	21.92	34.55	6.89	0.83
1988	22.24	35.20	7.02	0.58
1989	22.90	35.60	7.20	0.31
1990	23.08	36.00	7.44	0.32



C.I.F. OIL PRICE PATH
(ROUNDED TO NEAREST DOLLAR)

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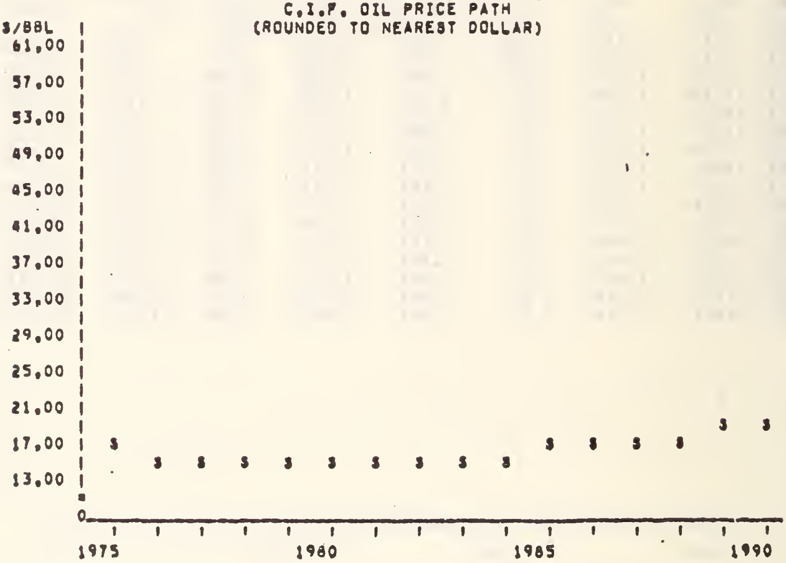
                    SCENARIO: IAL

YEAR   DUS        DCN       DJP       DEU       DLD       DOPEC      DWORLD
----   ---        ---       ---       ---       ---       ---        ----
 1975 16.29       1.59      4.57     13.30      6.48      2.04      44.27
 1976 16.79       1.69      5.23     14.10      8.92      2.18      48.91
 1977 17.93       1.76      5.38     14.00      8.76      2.32      50.15
 1978 18.92       1.88      5.78     14.31      6.96      2.47      52.32
 1979 19.45       1.99      6.18     14.62      9.47      2.63      54.34
 1980 19.27       2.00      6.22     14.38      9.76      2.78      54.40
 1981 17.43       2.03      6.36     14.18     10.06      2.94      53.00
 1982 17.93       2.10      6.50     13.96     10.31      3.04      53.84
 1983 18.53       2.07      6.59     13.69     10.55      3.25      54.68
 1984 17.04       2.15      6.86     13.74     10.89      3.40      54.08
 1985 17.41       2.25      7.22     13.98     11.33      3.56      55.75
 1986 17.71       2.32      7.45     14.29     11.73      3.80      57.31
 1987 18.12       2.41      7.72     14.66     12.06      4.10      59.07
 1988 18.60       2.50      7.94     14.92     12.48      4.40      60.85
 1989 19.13       2.58      8.14     15.32     12.70      4.60      62.47
 1990 19.82       2.66      8.31     15.60     12.90      4.80      64.08

YEAR     SUS        SCN      SJP      SEU        SLD        SSL      CMX       SWORLD
----     ---        ---      ---      ---        ---        ---      ---       ----
 1975    9.97      1.770    0.010    0.550      3.340      0.0       1.500    17.140
 1976    9.72      1.580    0.010    0.850      4.320      0.0       1.260    17.745
 1977    9.42      1.580    0.010    1.490      5.000      0.000     0.900    18.400
 1978   10.50      1.600    0.0      2.200      4.900      0.400     1.100    20.700
 1979   10.40      1.600    0.0      3.000      5.000      0.400     0.800    21.200
 1980   10.30      1.600    0.0      3.200      5.100      0.400     0.400    21.000
 1981    9.90      1.500    0.0      3.400      5.200      0.400    -1.000    19.400
 1982   10.01      1.532    0.0      3.576      5.517      0.400    -1.000    20.037
 1983   10.12      1.565    0.0      3.756      5.842      0.400    -1.000    20.683
 1984   10.26      1.603    0.0      3.847      6.197      0.400    -1.000    21.304
 1985   10.46      1.651    0.0      4.073      6.494      0.400    -1.000    22.075
 1986   10.85      1.696    0.0      4.183      7.122      0.400    -1.000    23.253
 1987   11.23      1.621    0.0      4.399      7.872      0.400    -1.000    24.521
 1988   11.59      1.655    0.0      4.493      8.513      0.400    -1.000    25.648
 1989   11.93      1.686    0.0      4.698      9.155      0.400    -1.000    26.865
 1990   12.38      1.716    0.0      4.902      9.682      0.400    -1.000    28.079
```

SCENARIO: IAM

YEAR	CIF PRICE (78$/BBL)	OPEC PRODUCTION (MMB/D)	U.S. IMPORTS (MMB/D)	PER CENT REDUCTION IN INCOME
1975	16.58	27.31	6.32	0.0
1976	15.32	31.05	7.06	0.0
1977	15.46	31.75	8.51	0.0
1978	14.50	30.83	8.12	0.0
1979	14.50	31.77	8.51	0.0
1980	14.50	33.57	9.23	0.0
1981	14.63	36.20	9.52	0.02
1982	14.63	36.01	9.78	0.04
1983	14.63	37.87	10.63	0.06
1984	15.05	39.20	11.39	0.23
1985	16.03	40.20	11.39	0.53
1986	16.03	40.16	11.17	0.41
1987	16.03	40.52	11.04	0.30
1988	16.03	41.98	11.26	0.20
1989	18.44	42.50	11.36	0.33
1990	18.68	43.10	11.45	0.17



C.I.F. OIL PRICE PATH
(ROUNDED TO NEAREST DOLLAR)

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                    SCENARIO: IAM

YEAR   DUS        DCN       DJP       DEU       DLD      DOPEC     DWORLD
----   ---        ---       ---       ---       ---       ---       ----
 1975 16.29       1.77      4.57     13.30      6.48     2.04      44.45
 1976 16.79       1.58      5.23     14.10      8.92     2.18      48.80
 1977 17.93       1.76      5.38     14.00      8.76     2.32      50.15
 1978 18.62       1.69      5.78     14.31      8.96     2.47      51.83
 1979 19.11       1.76      6.18     14.62      9.47     2.63      53.77
 1980 19.83       1.88      6.58     14.93      9.97     2.78      55.97
 1981 20.22       1.99      6.97     15.62     10.47     2.94      58.20
 1982 20.48       2.10      7.36     15.51     10.96     3.09      59.51
 1983 21.44       2.22      7.75     16.77     11.47     3.25      62.89
 1984 22.21       2.32      8.08     17.10     11.92     3.40      65.04
 1985 22.32       2.38      8.32     17.86     12.32     3.56      66.76
 1986 22.22       2.50      8.40     17.81     12.57     3.90      67.39
 1987 22.28       2.58      8.59     17.86     13.14     4.20      68.65
 1988 22.67       2.87      8.99     18.06     13.62     4.80      71.01
 1989 22.93       2.88      9.53     17.91     13.87     5.20      72.32
 1990 23.18       2.93      9.82     17.82     14.86     5.60      74.20

YEAR     SUS        SCN      SJP      SEU        SLD       SSL    CMX        SWORLD
----     ---        ---       ---      ---       ---       ---    ---        ----
 1975    9.97     1.770     0.010    0.530     3.340     0.0       1.500    17.140
 1976    9.72     1.580     0.010    0.850     4.320     0.0       1.260    17.745
 1977    9.42     1.580     0.010    1.490     5.000     0.000     0.900    18.400
 1978   10.50     1.600     0.0      2.200     5.200     0.400     1.100    21.000
 1979   10.60     1.700     0.0      3.000     5.500     0.400     0.800    22.000
 1980   10.60     1.700     0.0      3.400     5.900     0.400     0.400    22.400
 1981   10.70     1.800     0.0      3.600     6.500     0.400    -1.000    22.000
 1982   10.70     1.600     0.0      3.900     7.700     0.400    -1.000    23.500
 1983   10.81     1.901     0.0      4.503     8.406     0.400    -1.000    25.019
 1984   10.82     1.903     0.0      4.707     9.013     0.400    -1.000    25.838
 1985   10.92     1.904     0.0      4.810     9.520     0.400    -1.000    26.556
 1986   11.05     1.909     0.0      4.823    10.048     0.400    -1.000    27.234
 1987   11.23     1.923     0.0      4.958    10.625     0.400    -1.000    28.138
 1988   11.40     1.935     0.0      5.091    11.201     0.400    -1.000    29.032
 1989   11.57     1.946     0.0      5.120    11.777     0.400    -1.000    29.815
 1990   11.73     1.956     0.0      5.249    12.763     0.400    -1.000    31.101
```

ATTACHMENT

Department of Energy
Washington, D.C. 20461

MAY 2 1978

MEMORANDUM

TO: Mark E. Rodekohr
Energy Information Administration

FROM: Herman T. Franssen
Director, Office of Market Analysis
International Affairs

SUBJECT: DATA FOR THE OMS RUNS

Attached herewith is the data for the OMS runs we discussed. I have disaggregated world oil demand and non-OPEC supply by region to fit the OMS model.

I would like to have the following cases run:

1977 - 1990

A. Low demand (63.4 million b/d in 1985 and 71.8 million b/d in 1990); low non-OPEC supply (23.7 million b/d in 1990); OPEC constrained to 34.4 million b/d in 1985 and 36.0 million b/d in 1990; 2.5 million b/d Soviet imports.

B. High demand (68.4 million b/d in 1985 and 78.2 million b/d in 1990); high non-OPEC supply (27.9 million b/d in 1985 and 31.2 million b/d in 1990); OPEC constrained to 41.2 million b/d in 1985 and 43.1 million b/d in 1990; 2.5 million b/d Soviet imports.

C. Like A, but with no Soviet imports throughout 1990.

D. Like B, but with no Soviet imports throughout 1990.

E. Low demand; high non-OPEC supply; OPEC constrained to 41.2 million b/d in 1985 and 43.1 million b/d in 1990; 2.5 million b/d Soviet imports.

F. Like E, but with no Soviet imports throughout 1990.

G. High demand; low non-OPEC supply; OPEC constrained to 34.4 million b/d in 1985 and 36.0 million b/d in 1990; 2.5 million b/d Soviet oil imports.

H. Like G, but without Soviet imports throughout 1990.

Attachments

World Oil Demand, 1977-90

Low Case

	U.S.	DLN	DJP	DEU	DLD	D OPEC	D. World
1977	18.38	1.76	5.38	14.00	8.46	2.32	50.0
1978	18.92	1.88	5.78	14.31	8.96	2.47	51.5
1979	19.45	1.99	6.18	14.62	9.47	2.63	53.0
1980	19.89	2.11	6.58	14.93	9.97	2.78	54.6
1981	18.44	2.23	6.98	15.24	10.48	2.94	56.3
1982	19.46	2.39	7.38	15.55	10.98	3.04	58.0
1983	20.66	2.46	7.78	15.85	11.49	3.25	59.7
1984	19.18	2.53	8.18	16.16	11.99	3.40	61.5
1985	19.59	2.70	8.58	16.47	12.50	3.56	63.4
1986	20.0	2.80	-8.7	16.8	12.9	3.8	65.0
1987	20.4	2.90	8.9	17.1	13.2	4.1	66.6
1988	20.9	3.00	9.1	17.3	13.6	4.4	68.3
1989	21.5	3.10	9.3	17.7	13.8	4.6	70.0
1990	22.3	3.20	9.5	18.0	14.0	4.8	71.8

High Case

	U.S.	DLN	DJP	DEU	DLD	D OPEC	D. World
1977	18.38	1.59	5.38	14.00	8.46	2.32	50.0
1978	18.62	1.69	5.78	14.31	8.96	2.47	52.0
1979	19.11	1.76	6.18	14.62	9.47	2.63	54.0
1980	19.83	1.88	6.58	14.93	9.97	2.78	56.2
1981	20.24	1.99	6.98	15.64	10.48	2.94	58.5
1982	20.52	2.11	7.38	15.55	10.98	3.09	60.8
1983	21.49	2.23	7.78	16.82	11.49	3.25	63.3
1984	22.37	2.35	8.18	17.27	11.99	3.40	65.8
1985	22.75	2.46	8.58	18.31	12.50	3.56	68.4
1986	22.8	2.6	8.7	18.4	12.8	3.9	69.2
1987	22.9	2.7	8.9	18.5	13.4	4.2	70.6
1988	23.3	3.0	9.3	18.7	13.9	4.8	73.0
1989	24.0	3.1	10.1	18.9	14.3	5.2	75.6
1990	24.5	3.2	10.5	19.0	15.4	5.6	78.2

Non-OPEC Oil Supply (million b/d)

High

	S.US	SCN	SJP	SEW	SLD	SSL	CMX H	–	S World
1977	10.5	1.6	0.0	1.4	4.8	0.4	0.9	.9	19.6
1978	10.5	1.6	0.0	2.2	5.2	0.4	1.1	1.1	21.0
1979	10.6	1.7	0.0	3.0	5.5	0.4	0.8	.8	22.0
1980	10.6	1.7	0.0	3.4	5.9	0.4	0.4	.4	22.4
1981	10.7	1.8	0.0	3.6	6.5	0.4	-0.1	0	22.9
1982	10.7	1.8	0.0	3.9	7.7	0.4	-0.6	0	23.9
1983	10.8	1.9	0.0	4.5	8.4	0.4	-1.2	0	24.8
1984	10.8	1.9	0.0	4.7	9.0	0.4	-1.8	0	25.0
1985	10.9	1.9	0.0	4.8	9.5	0.4	-2.5	0	24.0
1986	11.0	1.9	0.0	4.8	10.0	0.4	-2.5	0	25.6
1987	11.1	1.9	0.0	4.9	10.5	0.4	-2.5	0	26.3
1988	11.2	1.9	0.0	5.0	11.0	0.4	-2.5	0	27.0
1989	11.3	1.9	0.0	5.0	11.5	0.4	-2.5	0	27.6
1990	11.4	1.9	0.0	5.1	12.4	0.4	-2.5	0	28.7

Low

1977	10.5	1.6	0.0	1.4	4.8	0.4	0.9	19.6
1978	10.5	1.6	0.0	2.2	4.9	0.4	1.1	20.7
1979	10.4	1.6	0.0	3.0	5.0	0.4	0.8	21.2
1980	10.3	1.6	0.0	3.2	5.1	0.4	0.4	21.0
1981	9.9	1.5	0.0	3.4	5.2	0.4	-0.1	20.3
1982	9.8	1.5	0.0	3.5	5.4	0.4	-0.6	20.0
1983	9.7	1.5	0.0	3.6	5.6	0.4	-1.2	19.6
1984	9.6	1.5	0.0	3.6	5.8	0.4	-1.8	19.1
1985	9.5	1.5	0.0	3.7	5.9	0.4	-2.5	18.5
1986	9.6	1.5	0.0	3.7	6.3	0.4	-2.5	19.0
1987	9.7	1.4	0.0	3.8	6.8	0.4	-2.5	19.5
1988	9.8	1.4	0.0	3.8	7.2	0.4	-2.5	20.1
1989	9.9	1.4	0.0	3.9	7.6	0.4	-2.5	20.7
1990	10.1	1.4	0.0	4.0	7.9	0.4	-2.5	21.3

Available OPEC Projection, 1977 - 1990

	Low	High
1977	33.2	33.2
1978	33.2	34.2
1979	33.4	35.2
1980	33.6	36.2
1981	33.8	37.2
1982	34.0	38.2
1983	34.2	39.2
1984	34.4	40.2
1985	34.4	41.2
1986	34.8	41.6
1987	35.2	42.0
1989	35.6	42.5
1990	36.0	43.1

LOW-LOW DEMANDS*

	U.S.	CANADA	JAPAN	EUROPE	LDC	OPEC
1978	18.92	1.88	5.78	14.31	8.96	2.47
1979	19.0	1.9	5.8	14.4	9.1	2.5
1980	19.2	2.1	6.1	14.5	9.5	2.7
1981	19.4	2.2	6.3	14.6	9.9	3.0
1982	19.6	2.3	6.5	14.7	10.2	3.2
1983	19.5	2.4	6.7	14.9	10.5	3.4
1984	19.4	2.5	6.9	15.1	10.8	3.5
1985	19.5	2.6	7.1	15.4	11.0	3.5
1986	19.7	2.6	7.3	15.7	11.4	3.7
1987	20.0	2.8	7.6	16.0	11.7	4.0
1988	20.3	2.9	7.9	16.4	12.1	4.2
1989	20.8	3.0	8.2	16.8	12.4	4.4
1990	21.2	3.1	8.5	17.1	12.7	4.6

* Received over the phone from Herman Franssen.

CPE
NET OIL DEMAND*

	High	Mid	Low
1978	1.1	1.1	1.1
1979	0.8	0.8	0.8
1980	0.4	0.4	0.4
1981	-0.1	-1.0	0
1982	-0.6	-1.0	0
1983	-1.2	-1.0	0
1984	-1.8	-1.0	0
1985	-2.5	-1.0	0
1986	-2.5	-1.0	0
1987	-2.5	-1.0	0
1988	-2.5	-1.0	0
1989	-2.5	-1.0	0
1990	-2.5	-1.0	0

*Mid and Low estimates received over the phone from Herman Franssen.

APPENDIX II

Department of Energy
Washington, D.C. 20545

ANALYSIS MEMORANDUM
No. AM/IA - 7805

AN EVALUATION OF FUTURE WORLD OIL PRICES

"This paper provides a preliminary analysis of the range of possible world oil prices during the 1980's. These preliminary price estimates were developed in support of the preparation of a National Energy Supply Strategy (NESS) and are subject to change as that study progresses."

Prepared by:

EIA National Energy Supply Strategy Project Team

Project Coordinator: Kenneth L. Kincel

Integrator and Writers:

Calvin Kilgore and Mark Rodekohr

Office of Integrative Analysis
Applied Analysis
Energy Information Administration

June 2, 1978

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ACKNOWLEDGEMENTS

This analysis could not have been completed without the help of many contributors which constituted the EIA National Energy Supply Strategy (NESS) Project team. Overall guidance in structuring the analysis was provided by Kenneth Kincel. Estimation of United States oil supply potential was accomplished by David Hulett and Charles Everett. The Project Independence Evaluation System (PIES) simulations were run by Frank Hopkins, Fred Murphy and Hilda McDaniel. The International Energy Evaluation System (IEES) simulations were done by Henry Weigel and Derriel Cato. The Oil Market Simulation (OMS) model was run by David Guthrie and the macroeconomic analyses were provided by Jerry Lagace, Stan Paul, Bill Rice, David Sandoval and Robert Schnapp. Particular guidance was obtained in the early stages of the analysis from John Pearson. Cal Kilgore and Mark Rodekohr were responsible for integrating the results and for coordinating the report preparation. Questions should be referred to W. Kilgore (566-9397) or M. Rodekohr (566-9515).

I. EXECUTIVE SUMMARY

Purpose

The purpose of this paper is to present a preliminary analysis of the range of possible world oil prices between now and the year 1990 and to identify the problems inherent in forecasting energy conditions at high world oil prices. The analysis was prepared in response to a request from the Office of Policy Evaluation, Department of Energy. The variables of major concern include the price of world oil, the rate of economic growth, and the level of oil production capacity of the Organization of Petroleum Exporting Countries (OPEC). World oil prices are determined as those prices which clear the energy market, given alternative estimates of world supply and demand.

It must be stressed at the outset that the results of this analysis are preliminary in that certain potentially significant issues have not yet been fully addressed. Some of these issues include:

- Possible unforeseen and radical responses of consumers to very high oil prices;
- The potential for drastic new policy measures when faced with large price increases;
- Advanced technological responses; and,
- Reduced oil consumption as a result of the National Energy Act (NEA) in the United States and similar legislation in other countries of the world.

While these issues are not treated explicitly in the current analysis, a more detailed study will follow which will address these areas of concern. Therefore, the results presented in this paper should be viewed as only an indication of future price trends based upon our understanding of the current world energy market. These price forecasts should not be viewed as an exact representation of the energy market in the 1980's.

Summary

The analysis presented in this paper documents an application of several EIA macroeconomic and energy models to the evaluation of higher world oil prices in the 1980's. Previous work, which was documented in Volume II of the Administrator's Annual Report, used these EIA models to assess a 5 percent annual real price increase during the 1980's. The work presented here is an assessment of more severe price increases and includes several adjustments that have been made to the models in order to assess the higher world oil prices. The major changes that were made to the models for this analysis include:

Data Resources, Inc. (DRI) Macroeconomic Model

- The DRI model was simulated at the higher prices in order to quantify the feedback effects on the economy and the results of these DRI simulations were then used to drive the PIES model; and,

- Several variables were adjusted in the DRI model to reflect the higher oil prices including energy prices, the foreign industrial production index, and potential GNP.

Project Independence Evaluation System (PIES)

- A low oil supply case was structured in which there is no increase in domestic production as a result of increased oil prices. This case reflects a very strict interpretation of current laws which allows price increases only at the rate of inflation;
- A high oil supply case was structured in which new domestic production is priced at the world level. In this case, it was assumed that due to imperfect perceptions of future prices, no withholding of production takes place; and,
- Multiple energy demand projections were used based upon five different levels of macroeconomic feedback on the economy due to the higher oil prices.

International Energy Evaluation System (IEES)

- The non-OPEC supply elasticities were modified to be consistent with the updated values determined in the PIES simulations;
- The foreign economic feedback elasticities were varied over a wide range in order to reflect uncertainty in the effects of the higher prices; and,
- The demands in the Less Developed Countries (LDC's) were made to be elastic with respect to price based upon International Bank for Reconstruction and Development (IBRD) estimates.

Each of the above models (DRI, PIES, and IEES) was simulated using a single price path for world oil which was quantified on the basis of preliminary runs of the Oil Market Simulation (OMS) model to increase at 14 percent per year with the first increase occurring in January 1981. The results of these simulations were then used to recalibrate the OMS price and income elasticities, and OMS was used to forecast revised oil prices under different levels of economic growth and OPEC production capacity.

The procedure used to make the final OMS oil price projections may be summarized as follows. A Reference case was specified which consists of mid-range world supply and demand projections for the years 1978 to 1990, with unconstrained OPEC production capacity and constant real world oil prices. This Reference case consists of the current mid-range EIA Projection Series C,[1/] which includes an average U.S. economic growth rate of approximately 3.8 percent per year over the period 1975-1990. In order to determine the sensitivity of the oil price forecasts to a lower economic growth assumption, a second scenario was defined which assumed a 1 percentage point lower than Reference case growth rate.

[1/] Projection Series C is taken from the EIA Annual Report to the Congress, Volume II.

For each of these economic growth scenarios, multiple ranges of world oil prices were determined by constraining the level of OPEC production and varying the level of economic response to higher oil prices. The resultant ranges of prices reflect uncertainty with respect to the level of future OPEC production capacity and the degree of sensitivity of world economies to increasing oil prices (termed "feedback"). The upper end of each price range assumes a pessimistic estimate of OPEC production potential (36.5 million barrels per day by 1990) and the lower end assumes an optimistic estimate (43.5 million barrels per day by 1990).

Figures 1 and 2 illustrate the projected ranges of oil prices for each economic growth case. Oil prices are expressed in real 1978 dollars per barrel delivered to the East Coast of the United States, which are the units to be used throughout this report. The difference between the two figures relates to the assumption regarding the impact of higher oil prices on the growth of economies outside of the United States. Because of the current lack of appropriate macroeconomic models of the foreign countries, it was possible only to bracket the economic feedbacks in the foreign countries using the feedbacks developed for the United States.

Figure 1

WORLD OIL PRICES: WITH OPTIMISTIC FOREIGN ECONOMIC FEEDBACK

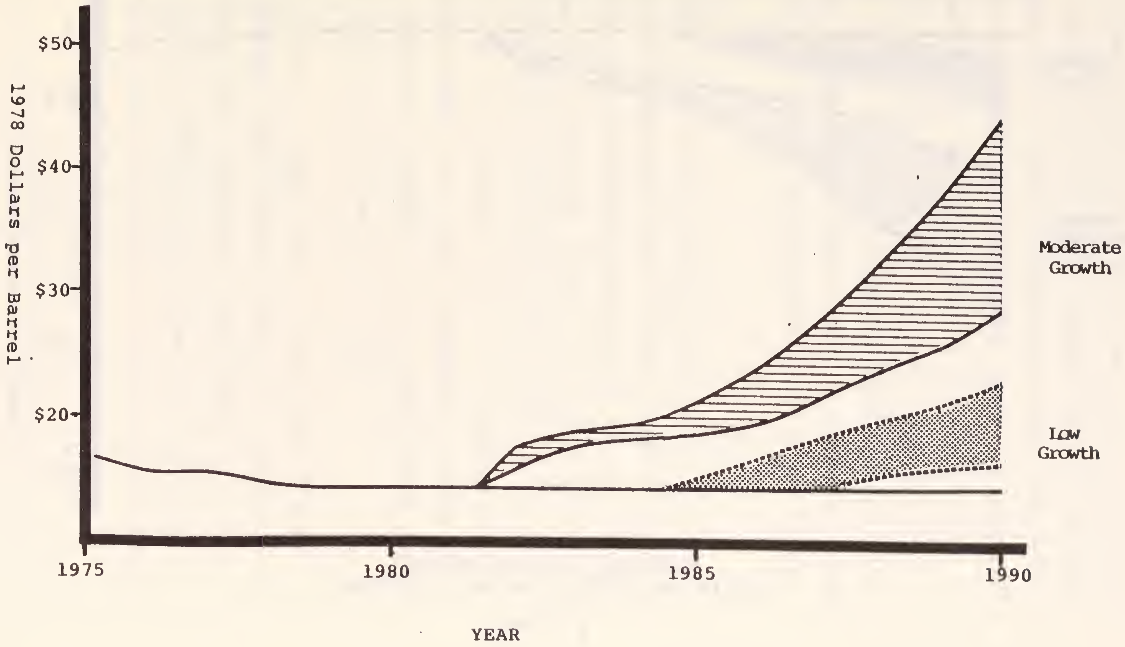


Figure 2

WORLD OIL PRICES: WITH PESSIMISTIC FOREIGN ECONOMIC FEEDBACK

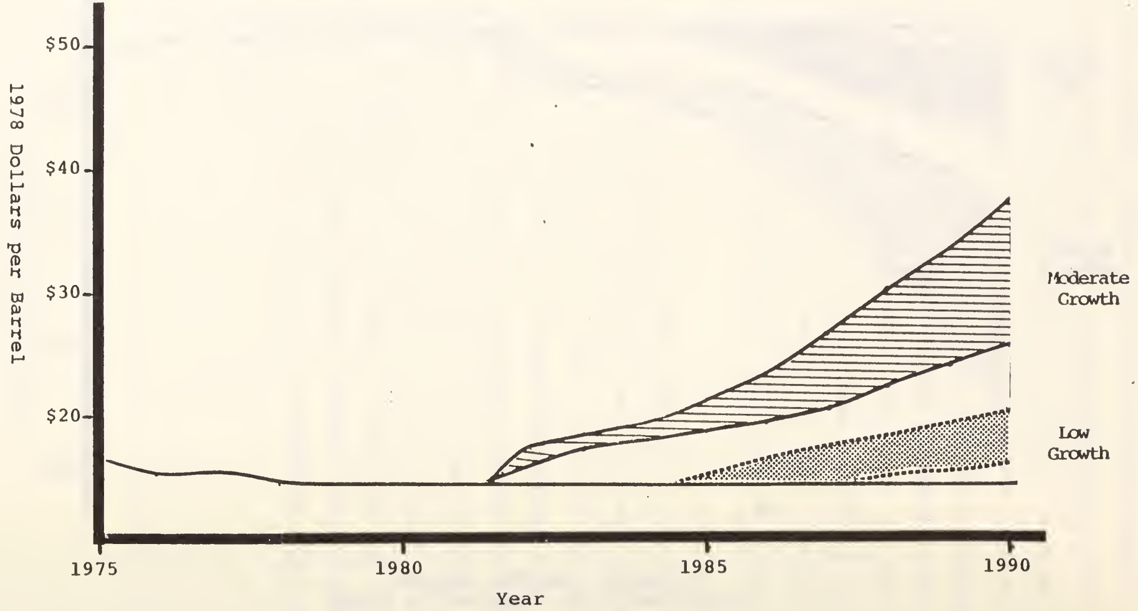


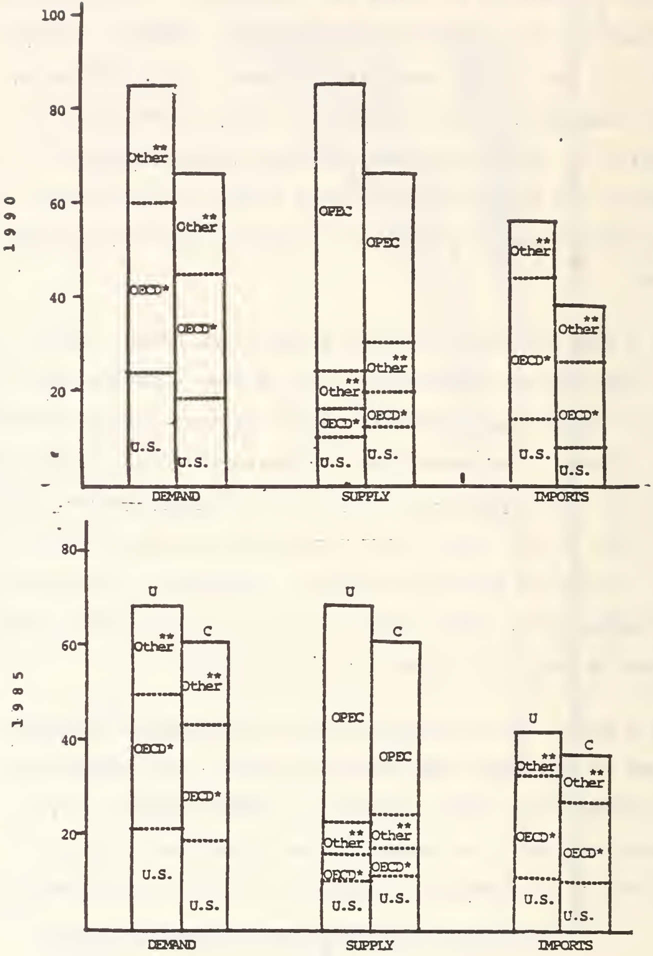
Figure 1 provides the oil price projections using an optimistic estimate of feedbacks in the foreign economies which assumes an impact equivalent to twice the optimistic rates derived for the United States. Under this assumption, moderate economic growth (3.8 percent in the United States) could lead to an initial real price rise by 1982 with prices reaching $29-44 per barrel by 1990. The lower economic growth scenario (2.8 percent in the United States) could result in real price rises by the 1985-88 period with prices reaching $16-23 per barrel by 1990.

Figure 2 provides the oil price projections using a pessimistic estimate of feedbacks in the foreign economies which is set at twice the pessimistic rates derived for the United States. Under this assumption, moderate economic growth would lead to an initial real price rise by the same year as above (1982), but prices would likely rise to the somewhat lower levels in 1990 of $26-37 per barrel. Similarly, in the low growth case, prices still begin to rise in the 1985-88 period but rise to only $16-21 per barrel in 1990.

Figure 3 shows the oil trade in the unconstrained Reference case and in the same case (moderate growth with optimistic foreign feedbacks) after imposing an OPEC production limit. The resultant price increase reduces demand and increases supply worldwide causing oil imports to fall in the consuming

FIGURE 3

Demand, Supply, and Imports by Region
(MMB/D)



U - Unconstrained Reference case.
C - Constrained Moderate growth case.
* - Excluding the U.S. and Australia/New Zealand.
** - Includes Australia/New Zealand.

countries. The figure shows the effects in both 1985 and 1990 of higher oil prices and illustrates the median adjustments that take place in each area of the world.

In summary, the principal results of this preliminary analysis are as follows:

- Under the moderate growth assumption (3.8 percent in the U.S.), the price of world oil could be between $19 and $21 per barrel by 1985 and $26 and $44 per barrel by 1990 if 1990 OPEC capacity is constrained to 36.5-43.5 million barrels per day;
- If economic growth proves to be less than 3 percent, then little or no price increases seem likely before 1985 although prices could rise to between $16 and $23 per barrel by 1990;
- Clearly the most sensitive assumption in projecting oil prices is the level of future economic growth;
- It is possible that United States oil production could increase by as much as 3.2 million barrels per day by 1990 given a 14 percent annual price increase;
- The feedback on the United States economy of higher world oil prices could be less than previously expected. It is possible that much of the adverse effect on the economy of a steady price rise throughout the 1980's could be overcome by the year 1990; and,
- One of the most sensitive variables affecting the degree of adjustment of the U.S. economy to the higher oil prices is the domestic production response. If U.S. production fails to increase with the higher prices, the effects on the the economy could be very severe.

In a second phase of this analysis, EIA will investigate other aspects of the world energy situation which must be addressed before a final EIA projection of world oil prices can be obtained. These include:

- An examination of possible non-linear demand responses to very high world oil prices;
- The potential for significant new non-price related conservation measures;
- The potential for accelerated development of new sources of energy such as solar, geothermal, etc; and,
- The potential impacts of the National Energy Act (NEA) in the United States and similar legislation in other countries of the world.

II. INTRODUCTION

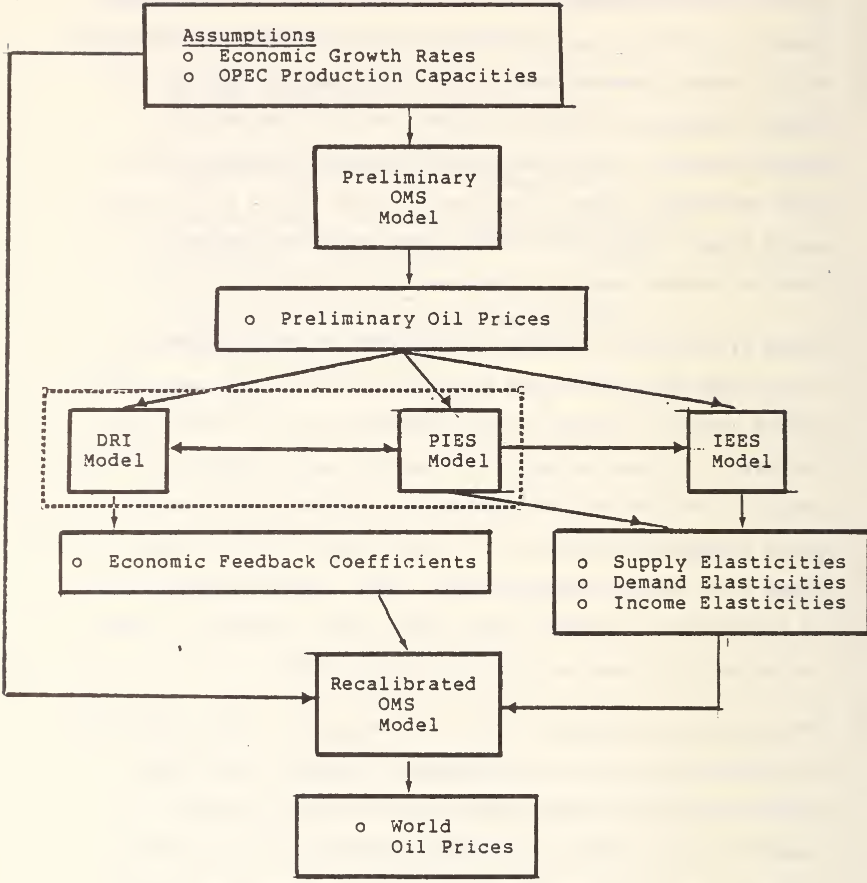
This analysis of world oil prices was initiated by making preliminary estimates of future prices using the Oil Market Simulation (OMS) computer model. OMS is a semi-reduced form of the several macroeconomic and energy models used by the Energy Information Administration for the forecasting of energy markets. This preliminary analysis indicated that, with reasonable rates of economic growth, world oil prices could dramatically rise in the 1980-1990 time period with 1990 prices increasing to between $35 and $55 per barrel.

These preliminary findings were derived from a calibration of the OMS model which was based upon runs of the larger EIA models with oil prices in the neighborhood of $15 per barrel. Therefore, it was necessary to run the larger models at higher world oil prices in order to further quantify the non-oil price responses and some of the associated uncertainties. Based upon the preliminary runs of OMS, a price increase of 14 percent per year was chosen with prices starting to rise in January 1981 and continuing through 1990.

The analysis proceeded as shown in Figure 4. After obtaining the preliminary oil price estimates from OMS, the large macroeconomic and energy models were used to simulate the impacts on the economy and energy markets of the higher oil prices. The Data Resources Inc. (DRI) macroeconomic model

FIGURE 4

Overview of Analysis Methodology



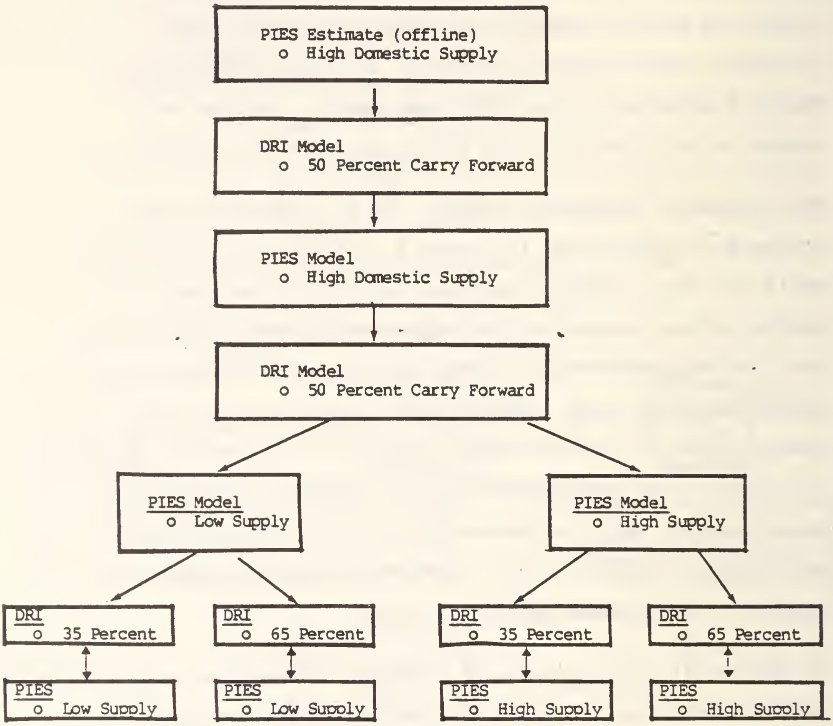
was used to examine the impact of higher prices on the United States economy. Given the resulting economic conditions, the Project Independence Evaluation System (PIES) was used to examine the impact of the oil price increase on the U.S. energy sector; and the International Energy Evaluation System (IEES) was used to examine the impact of the price increase on the world energy markets.

The simulation technique used for the U.S. portion of the analysis is illustrated in Figure 5. Initially the 14 percent world oil price increase was used (offline) to estimate U.S. energy prices, production and imports which were then entered into the DRI macroeconomic model to compute an economic growth path over time. The economic growth path was then used as input to the PIES model along with the assumed world oil prices. The PIES model produced estimates of domestic energy prices, gasoline consumption and U.S. imports which were then entered back into the DRI macroeconomic model to produce a new economic growth forecast.

At this point, two of the more important parameters were varied, including: the level of domestic supply response to the higher world oil prices; and the rate at which the foreign industrial production indices contained in the DRI model could be expected to adjust to the higher prices. These parameters are referred to in Figure 5 as "low and high domestic supply"

FIGURE 5

Overview of United States Analysis



and as "35 and 65 percent carry forward." First, the domestic supply response was introduced by making a separate PIES run for each case and then the carry forward parameter was varied by making two DRI runs for each of the two PIES runs (See Figure 5).

The resultant four DRI model cases were input to PIES for a corresponding set of four PIES simulations. In theory the four resulting PIES solutions should be repeatedly rerun in the DRI model and then again in the PIES model until equilibrium is achieved where imports, prices and the other relevant macro variables remain unchanged from iteration to iteration. However, because of the large amount of computer time and other resources required for each iteration, this was not possible in the current analysis. Rather, the final four PIES cases were run only once. However, the resultant four PIES solutions were rerun in the DRI model in an attempt to quantify the degree to which true convergence had been achieved. (See Appendix A for details of the DRI model runs).

Once the United States models (DRI and PIES) had been simulated, the IEES model was used to determine supply and demand worldwide and to calculate the required rate of OPEC production.

The final phase of the analysis then used the simulations of the larger models to compute the implied supply and demand elasticities which were then input to the OMS model to produce revised forecasts of the market clearing world oil prices.

The remainder of this paper is organized into four sections including a description of the macroeconomic simulations, the PIES model simulations, the IEES model simulations, and a detailed specification of the world oil price projections.

III. MACROECONOMIC SIMULATIONS

The macroeconomic assumptions used in the analysis are based upon the Series C projection given in the EIA Administrator's Annual Report. However, that projection assumed the maintainance of constant world oil prices (at less than $15 per barrel) to the year 1990 and thus had to be modified to reflect the 14 percent annual price increase assumption. Using the higher oil prices, four estimates were made of economic impact in terms of real GNP reduction. These four simulations of the DRI model include two levels of domestic oil production and two rates of decay of adverse foreign economic impacts over time.

The most significant factor affecting the economic impacts is the responsiveness of domestic oil production to the rising world oil prices. This is because increased U.S. production results in direct reductions in oil imports and their associated foreign expenditures. As indicated in Table 1, the adverse economic impacts are far greater when U.S. production does not increase in response to the higher prices.

The second most significant factor in the DRI simulations is the rate (termed the "carry-forward" rate) at which the foreign industrial production indices contained in the DRI model are assumed to adjust to higher world oil prices. That is to say, the extent to which any reduction in the foreign

TABLE 1

Percent Change in Real U.S. GNP from the Reference Case

	High U.S. Production		Low U.S. Production	
Year	Low 1/ Feedback	High 1/ Feedback	Low 1/ Feedback	High 1/ Feedback
1978	0.0	0.0	0.0	0.0
1979	0.0	0.0	0.0	0.0
1980	0.0	0.0	0.0	0.0
1981	-0.2	-0.2	-0.2	-0.3
1982	-1.2	-1.2	-1.2	-1.2
1983	-2.3	-2.5	-2.4	-2.6
1984	-3.1	-3.6	-3.2	-3.7
1985	-3.3	-4.3	-3.6	-4.6
1986	-3.1	-4.6	-3.7	-5.2
1987	-2.6	-4.5	-3.8	-5.6
1988	-2.0	-4.2	-4.0	-6.1
1989	-1.6	-3.9	-4.4	-6.9
1990	-1.2	-3.6	-5.6	-8.5

1/ Low Feedback assumes a 35 percent carry-forward factor on the foreign industrial index and High Feedback assumes a 65 percent carry-forward factor.

industrial production indices that occurs in a given year is assumed to be carried forward to the next year. The level that one should assume for this variable is not certain, but it seems probable that the rate lies somewhere between 35 and 65 percent. As shown in Table 1, the economic impacts that result from these two carry-forward percentage levels are significantly different and they serve to quantify the uncertainty in the macro model regarding the adjustments to the foreign industrial production indices.

Each simulation was also made by altering a number of additional variables in the macro model which reflect the major impacts of higher world oil prices. The additional variables modified include:

- The price of gasoline and value of gasoline consumption,
- the wholesale price index for all energy and power,
- the price index and value of imported oil; and,
- potential real GNP.

U.S. potential real GNP was reduced to reflect the estimated effect on this variable of slower rates of increase in capital stocks as a result of the depressing effect of the oil price increases on domestic economic activity. As described in Appendix A, these reductions in potential GNP varied between 0.8 and 1.0 percent in 1985 and between 2.1 and 2.8 percent in 1990. A more detailed discussion of the macroeconomic simulations is given in Appendix A.

In order to simulate the desired U.S. macroeconomic responses in the OMS model, it was necessary to express the reductions in economic growth given in Table 1 in terms of economic feedback elasticities. In OMS, the feedback elasticities are defined as the expected percent reduction in GNP that would be caused by a one percent increase in the world oil price. The elasticities for the United States that were obtained in the high domestic production case are given in Table 2.

In order to simulate corresponding economic feedback effects outside of the United States, it was necessary to range the possible foreign effects based upon the results obtained for the U.S. The procedure used was to double the feedbacks obtained for the United States under both the high and low production response cases in order to obtain optimistic and pessimistic estimates of the foreign feedbacks. The reason for the doubling of the U.S. rates is to reflect the higher vulnerability of most foreign economies to the higher oil prices. It is recognized that this is a poor substitute for having an international macroeconomic model and it is EIA's intention to seek to improve this situation in the future. However, the procedure utilized here of ranging the possible foreign feedback effects does serve to bracket their impacts on the world oil price projections. It will be shown in Section VI of this report that the uncertainty in the 1990 oil price projections is increased by as much as $7 per barrel due to this approximation.

TABLE 2

Feedback Elasticity Estimates [1/]

Year	United States 2/		Foreign			
			Optimistic 4/		Pessimistic 4/	
	Low 3/ Feedback	High 3/ Feedback	Low Feedback	High Feedback	Low Feedback	High Feedback
1978	0.0	0.0	0.0	0.0	0.0	0.0
1979	0.0	0.0	0.0	0.0	0.0	0.0
1980	0.0	0.0	0.0	0.0	0.0	0.0
1981	-0.02	-0.02	-0.04	-0.04	-0.04	-0.04
1982	-0.05	-0.05	-0.10	-0.10	-0.10	-0.10
1983	-0.06	-0.07	-0.12	-0.14	-0.12	-0.14
1984	-0.06	-0.07	-0.12	-0.14	-0.13	-0.15
1985	-0.05	-0.07	-0.10	-0.14	-0.11	-0.15
1986	-0.04	-0.06	-0.08	-0.12	-0.10	-0.14
1987	-0.03	-0.05	-0.06	-0.10	-0.09	-0.13
1988	-0.02	-0.04	-0.04	-0.08	-0.08	-0.12
1989	-0.01	-0.03	-0.02	-0.06	-0.08	-0.12
1990	-0.01	-0.03	-0.02	-0.06	-0.09	-0.14

1/ The feedback elasticity is defined to be the expected percent change in economic activity associated with a one percent increase in the world oil price. For example, in 1985 the logarithm of one plus the percent change in economic growth (1+ .043 in Table 1) is divided by the logarithm of one plus the percent change in price (1.90) to yield a feedback elasticity of -.07.

2/ Based upon the high domestic oil production case from Table 1.

3/ Low Feedback assumes a 35 percent carry-forward factor for the foreign industrial indices and High Feedback assumes a 65 percent carry-forward factor.

4/ The optimistic and pessimistic foreign feedback elasticities are derived from a doubling of the GNP reductions given in Table 1 for the high and low U.S. production responses respectively.

IV. PIES MODEL SIMULATIONS

This section discusses the major assumptions and results of the PIES model simulations of the U.S. energy market. The principal assumptions contained on the supply side of the model include:

- The EPCA oil pricing regulations are assumed to remain in effect, in some form, through 1990;
- An entitlements program is assumed which equalizes refiner acquisition costs;
- Resource levels are assumed to equal the median level stated in USGS circular 725;
- The leasing schedule includes the Department of the Interior's forecast of OCS lease sales of 8.5 million acres thru 1981 and four lease sales per year of a million acres per sale from 1982 to 1990;
- In the high domestic supply case, a new law is enacted which insures the continued pricing of newly discovered oil at the marginal world oil price;
- Producers are assumed not to speculatively withold production. This assumption is necessary in the higher price cases where the rate of return on investment is exceeded by the oil price increases; and,
- Current legislation is assumed to apply for all non-oil energy supplies including a continuation of natural gas regulation.

On the demand side, the assumptions are conservation related and deal only with existing laws. There are five major conservation programs included in the analysis. These programs include:

- Weatherization of homes program which provides financial assistance to low-income families;
- Federal energy management program which requires a 20 percent reduction in energy consumption in Federal buildings;
- New car fuel economy standards assuming a 23.6 miles per gallon standard by 1985;
- Appliance efficiency standards requiring that the sales weighted average of a select group of appliances be made 20 percent more efficient in 1980 as compared to 1972; and,
- State energy conservation programs which provide for residential building standards.

These and other PIES model assumptions are more fully discussed in Volume II of the EIA Administrator's Annual Report, Projection Series C.

A total of seven scenarios were simulated using the PIES model. These scenarios are listed in Table 3 and involve differing assumptions regarding the world oil price increase, the level of feedback on the U.S. economy of the increasing oil prices and the level of response of U.S. production to the higher prices.

The results of the PIES simulations are summarized in Tables 4 and 5 for the years 1985 and 1990. Table 4 indicates the aggregate levels of U.S. demand, indigenous production and net imports of petroleum for each of the seven scenarios. Table 5 summarizes the demand responses in 1990 in terms of changes in individual economic sectors.

TABLE 3

PIES Model Scenarios

Scenario 4/	Annual Oil Price 1/ Increase	Macroeconomic 2/ Response	U.S. 3/ Production
1	None	--	--
2	14%	No response to higher prices	No Response To Prices
3	14%	Low feedback	No Response To Prices
4	14%	High feedback	No Response To Prices
5	14%	No response to higher prices	High Response To Prices
6	14%	Low feedback	High Response To Prices
7	14%	High feedback	High Response To Prices

1/ Price increases reflect annual increases in the real price of world oil beginning in January 1981 and continuing through the year 1990.

2/ Low and high feedback effects are given in Table 1.

3/ Low and high U.S. production reflects differences in the level of regulated prices of newly discovered domestic oil.

4/ Projection Series C, Administrator's Annual Report, Volume II.

TABLE 4

U.S. Oil Demand, Indigenous Production, and Net Imports (MMB/D)

	Scenario			Demand 2/		Indigenous Production		Net Oil Imports	
	Annual Oil Price Increase 1/	Production Response	Macroeconomic Response	1985	1990	1985	1990	1985	1990
1.	None 3/	--	--	21.3	23.5	10.2	9.8	11.1	13.7
2.	14%	None	None	19.6	19.1	10.2	9.8	9.4	9.3
3.	14%	None	Low	18.5	17.6	10.2	9.8	8.3	7.8
4.	14%	None	High	18.2	17.0	10.2	9.8	8.0	7.2
5.	14%	High	None	19.2	17.7	10.9	13.0	8.3	4.7
6.	14%	High	Low	18.1	17.5	10.9	13.0	7.2	4.5
7.	14%	High	High	17.8	16.9	10.9	13.0	6.9	3.9

1/ Annual price increases begin in January 1981.
2/ Demand for oil is expressed in crude oil equivalents and excludes processing gains in the refinery.
3/ EIA Projection Series C.

TABLE 5

Sectoral Comparison of 1990 Oil Consumption, United States
(MMB/D)

Scenario			Economic Sector						
Annual Oil Price Increase 1/	Production Response	Macroeconomic Response	Residential	Commercial	Industrial	Transportation	Electric Generation	Other/ Gains	Total 2/
1. None 3/	--	--	2.1	1.8	7.0	11.7	1.2	-0.3	23.5
2. 14%	None	None	1.4	1.4	5.6	10.7	0.3	-0.3	19.1
3. 14%	None	Low	1.4	1.3	5.2	9.6	0.3	-0.2	17.6
4. 14%	None	High	1.4	1.2	5.0	9.2	0.3	-0.1	17.0
5. 14%	High	None	1.2	1.2	5.3	9.9	0.3	-0.2	17.7
6. 14%	High	Low	1.2	1.2	5.2	9.8	0.3	-0.2	17.5
7. 14%	High	High	1.1	1.1	5.0	9.4	0.3	0.0	16.9

1/ Annual price increases begin in January 1981.
2/ Total consumption is expressed in crude oil equivalents and excludes volumetric processing gains in the refinery.
3/ EIA Projection Series C.

The principal points of interest obtained from the PIES simulations of the 14 percent annual oil price increase include:

- Higher oil prices could result in increases in U.S. production of as much as 3.2 million barrels per day by the year 1990;
- The demand response to the higher oil prices could range between 1.7 and 3.5 million barrels per day in 1985 and between 4.4 and 6.5 million barrels per day in 1990;
- Reduction in net imports could range between 1.7 and 3.9 million barrels per day in 1985 and between 4.4 and 9.8 million barrels per day by 1990; and,
- In absolute quantities, the industrial and transportation sectors experience the largest demand reductions, but the electric utility sector experiences the largest percentage reduction in oil demand.

V. IEES MODEL SIMULATIONS

This section describes the major assumptions and results of the IEES model simulations of international energy markets. Most of the international assumptions are the same as those used in EIA's mid-range forecast, Projection Series C, including the following:

- The moderate economic growth rates (at constant oil prices) given in Table 6;
- The non-OPEC supply estimates (at constant oil prices) of 23.7 million barrels per day in 1985 and 24.3 million barrels per day in 1990 as listed in Table 7; and,
- Net communist petroleum imports of 2.5 million barrels per day in 1985 and 1990.

The international assumptions that were altered for the higher oil price cases addressed in this paper include:

- All non-OPEC supply elasticities have been updated to the new supply responses determined for the United States. The assumption is that the political and organizational problems that exist in the other non-OPEC countries will roughly equate to the technical production constraints in the U.S. in the determination of price responsiveness;
- A range of foreign economic feedback elasticities were calibrated to the new levels given in Table 2. Both optimistic and pessimistic estimates were used based upon the estimates derived for the U.S. for the high and low import dependence (i.e. production response) cases. The U.S. feedbacks are doubled in order to reflect the much heavier dependence upon imports by the other non-OPEC countries;

- The demands in the Less Developed Countries (LDC's) were made to be elastic with respect to price based upon International Bank for Reconstruction and Development (IBRD) estimates 2/; and,
- The new high oil price PIES runs for the U.S. were incorporated in the international simulations.

Three scenarios were run using the IEES model corresponding to cases 5 and 7 of the PIES scenarios (see Table 3), as follows:

Corresponding PIES Scenario	Annual Oil Price Increase	Foreign Economic Feedback	Indigenous Production
5	14%	None	High Price Response
7	14%	Optimistic	High Price Response
7	14%	Pessimistic	High Price Response

It was not necessary to simulate the remaining United States scenarios with the IEES model, because those simulations were not needed to calibrate the Oil Market Simulation (OMS) model.

The results of the international simulations are given in Table 8 which gives world demand, non-OPEC production, and the implied requirements for OPEC oil in each case.

2/ "Energy and Petroleum in Non-OPEC Developing Countries, 1974-1980", WP-229, International Bank for Reconstruction and Development, February 1976.

TABLE 6

Reference Case Target Economic Growth Rates 1/

	1960-1973	1974-1975	1975-1985	1985-1990
United States	4.3	-1.5	4.2	3.1
Canada	5.5	0.6	4.2	3.1
Japan	10.3	2.1	5.6	5.6
OECD Europe	4.9	-2.9	3.6	3.8
Australia/ New Zealand	6.0	1.4	4.1	4.5
Developing Countries	5.6	3.8	6.6	6.2
OPEC	8.6	6.0	5.5	4.4

1/ Assumes the maintenance of current real world oil prices through the year 1990.

Source: EIA Projection Series C.

TABLE 7

Non-OPEC Oil Supply
Assumptions at Constant World Oil Prices 1/
(MMB/D)

	1975	1985	1990
United States	10.0	10.2	9.8
Canada	1.8	1.3	1.3
Japan	.0	.0	.0
OECD-Europe	0.6	4.5	5.0
LDC's/Other	5.0	7.7	8.2
Total Non-OPEC	17.4	23.7	24.3

1/ See Table B-2 for assumed price elasticities of supply in the non-OPEC regions.

Source: Projection Series C of Administrator's Annual Report, Volume II.

TABLE 8

World Oil Demand, Non-OPEC Production and Implied Demand for OPEC Oil (MMB/D)

Scenario			Free 3/ World Oil Demand		Non-OPEC Oil Production		Demand for OPEC Oil	
Annual Oil Price Increase 1/	Non-OPEC Production Response	Foreign 2/ Macroeconomic Response	1985	1990	1985	1990	1985	1990
None 4/	—	—	68.4	85.4	23.7	24.4	44.7	61.0
14%	High	None	62.2	68.1	25.1	32.4	37.1	35.7
14%	High	Optimistic	56.4	60.3	25.1	32.4	31.3	27.9
14%	High	Pessimistic	56.2	55.7	25.1	32.4	31.1	23.3

1/ Annual price increases begin in January 1981.
2/ See Table 2 for the optimistic and pessimistic foreign economic feedbacks. Both the U.S. and foreign macroeconomic feedbacks are based upon the high (65 percent carry-forward rate) cases.
3/ Includes net communist imports of 2.5 million barrels per day.
4/ EIA Projection Series C.

VI. WORLD OIL PRICE PROJECTIONS

World oil prices are affected by a number of factors, the most important of which is the rate of world economic growth which drives the demand for petroleum. These and other assumptions affecting the oil price forecasts may be summarized as follows:

- Moderate economic growth rates are as given in Table 6 and taken from EIA Projection Series C;
- A Low growth case was assumed to be one percentage point below the Moderate case shown in Table 6;
- Multiple economic response (or feedback elasticity) cases are used as summarized in Table 2;
- The feedback elasticity outside of the United States is assumed to be bracketed by a doubling of the optimistic and pessimistic elasticities in the U.S. to reflect the fact that other countries are more sensitive to oil price increases;
- Non-OPEC production potential at constant world oil prices is as given in Table 7 and is assumed to be elastic with respect to price; and,
- Two levels of OPEC production potential are assumed to be as given in Table 9 and are not assumed to be price elastic.

In order to establish the range of oil prices for each economic growth case, the high feedback simulations were made in conjunction with the optimistic OPEC production limits and the low feedback simulations were made with the pessimistic OPEC production limits given in Table 9. Two sets of oil price projections were made for each economic growth case in which the level of feedbacks in the foreign economies was varied

TABLE 9

Range of OPEC Production Potential 1/
(MMB/D)

Country	1985 Pessimistic	1985 Optimistic	1990 Pessimistic	1990 Optimistic
Saudi Arabia	10.0	12.0	12.0	17.0
Kuwait	3.0	3.0	3.0	4.3
United Arab Emirates	3.0	3.0	2.5	3.2
Other Arab OPEC	8.0	8.0	8.3	8.3
Other OPEC	12.8	12.8	10.7	10.7
Total OPEC	36.8	38.8	36.5	43.5

1/ Source: EIA Annual Report to the Congress, Volume II, Table 4.14.

separately over a wide range. The results of these price projections were given previously in Figures 1 and 2 and are summarized in Table 10.

The oil price estimates were made using the OMS model, for which a detailed description is given in Appendix B. OMS first calculates the demand for OPEC oil by summing the demands for oil in the various regions of the world. These regional demands are based on simulations of the larger energy models and are entered exogenously into OMS. The resultant demand for OPEC oil is compared to the OPEC production limit, and if this limit is exceeded, prices are allowed to rise until the market is cleared. The amount by which prices increase is determined by the demand, supply and economic feedback elasticities which were calculated from the simulations of the larger macroeconomic and energy models.

Table 10 summarizes the results of the OMS model runs for the two growth rate cases under both optimistic and pessimistic foreign feedback assumptions. The table shows the year in which the price is expected to increase and the expected world oil price in 1985 and 1990. The principal results are:

- World oil prices could be influenced strongly by economic growth rates in the 1980's;
- There is a wide range of uncertainty on the magnitude of possible world oil prices in the 1980's;

TABLE 10

Summary of World Oil Price Analysis

Optimistic Foreign 3/ Economic Feedback	Year of Initial Price Increase	World Oil Price 1/		Percent Economic Impact 2/			
				1985		1990	
		1985	1990	U.S.	Foreign	U.S.	Foreign
Moderate Growth							
Low Prices 4/	1982	19.00	29.00	1.9	3.8	2.3	4.6
High Prices 5/	1982	21.00	44.00	2.3	4.6	1.5	3.0
Low Growth							
Low Prices	1988	14.50	16.00	0.0	0.0	0.7	1.4
High Prices	1985	15.00	23.00	0.1	0.1	1.9	3.8
Pessimistic Foreign 3/ Economic Feedbacks							
Moderate Growth							
Low Prices	1982	19.00	26.00	1.9	3.8	2.0	6.9
HIgh Prices	1982	21.00	37.00	2.3	4.7	1.3	7.2
Low Growth							
Low Prices	1988	14.50	16.00	0.0	0.0	0.7	1.5
High Prices	1985	15.00	21.00	0.1	0.1	1.5	3.6

1/ Prices are stated in 1978 dollars per barrel, C.I.F East Coast of the United States.

2/ Economic impacts are stated as percent reduction in economic activity (real GNP).

3/ Optimistic and pessimistic foreign economic feedbacks are derived from the high and low cases, respectiviely, of U.S. production responses (see Table 2).

4/ Assumes high economic feedback from world oil prices (see Table 2) and optimistic OPEC production (see Table 9).

5/ Assumes low economic feedback from world oil prices (see Table 2) and pessimistic OPEC production (see Table 9).

- Under the moderate economic growth assumptions, 1990 prices could range between $26 and $44 per barrel; and,
- Under low economic growth assumptions, world oil prices are not likely to rise before 1985 and could still be as low as $16 per barrel in 1990.

Furthermore, Table 10 presents the macroeconomic impacts, or reductions in economic growth implied by each of the scenarios. This analysis shows that:

- Higher world oil prices are likely to depress economic growth in the 1980's;
- In some cases, the economic impact could be greater in 1985 than it is in 1990;
- Economic activity in the United States could be depressed by as much as 2.3 percent in both 1985 and 1990, assuming high production responses. With low production responses, the depressive effect would be significantly more severe; and,
- Economic impacts outside of the United States are highly uncertain and could vary between 1.4 and 7.2 percent by the year 1990.

As stated previously, the analysis of world oil prices given in this paper is preliminary. In a second phase of the analysis, EIA will investigate other aspects of the world energy situation which must be addressed before a final EIA projection of world oil prices can be obtained. These include:

- An examination of possible non-linear demand responses to very high world oil prices;
- The potential for significant new non-price related conservation measures;
- The potential for accelerated development of new sources of energy such as solar, geothermal, etc; and,
- The potential impacts of the National Energy Act (NEA) in the United States and similar legislation in other countries of the world.

Appendix A

Macroeconomic Effects of Increasing Real World Oil Prices

INTRODUCTION

This appendix is part of a larger effort whose objective is to develop a National Energy Supply Strategy (NESS) based on likely future world economic growth rates, world oil prices, other energy developments, and their interrelationship. The present effort is limited to estimating the effects of one set of future real world oil prices on the U.S. economy. These prices reflect specific assumptions concerning world economic growth. The effects estimated are only approximations since, for purposes of this appendix, they are not in turn allowed to affect world energy prices.

Methodology and Assumptions

This section discusses the methodology and assumptions used to estimate the impacts on the U.S. national economy that could result from increasing real world oil prices. These prices reflect specific assumptions concerning world economic growth and the crude oil productive capacity of the Organization of Petroleum Exporting Countries (OPEC). Estimates of the effects of these prices on the energy sector of the U.S. economy, on potential U.S. GNP, and on foreign industrialized economies were incorporated into the Data Resources, Inc. (DRI) Quarterly Econometric Model. The DRI model was then solved and the solution was compared against a solution based on constant real world oil prices. The latter solution is the Scenario, or Series, C solution in the EIA Administrator's Annual Report. The differences between the increasing real world oil price and Scenario C solutions constitute the impacts on the U.S. national economy. Sensitivity analyses were made for selected variables in the increasing real world oil price solution.

The increasing oil prices were estimated with use of an Oil Market Simulation (OMS) Model and are based on the assumption that OPEC crude oil productive capacity is 37 million barrels per day throughout the 1977-90 interval. They are also based on assumed growth rates for the world's economies during the 1977 through 1990 period. The lower the growth rate the lower is the real world oil price. The growth rate assumed for U.S. real Gross National Product (GNP) is 4.8 percent. This high growth assumption resulted in a $55 per barrel real (1978 dollars) world crude oil price in 1990. This price is listed in Table A-1 and differs significantly from a constant real price of about $15 for Scenario C. Prices associated with low and intermediate U.S. growth rates are also listed in the table but their effects on the U.S. economy are not estimated in this paper. Rates of economic growth for the rest of the world are not presented in Table A-1 but they do differ from those for the United States. A detailed exposition of the OMS model and assumptions used to generate prices is given in Appendix B.

Table A-1

Preliminary Assumptions and World Crude Oil Prices[1]

	Selected Assumptions		World Oil Prices			
NESS Scenario	Annual Rate of Increase in U.S. Real GNP, 1975-90 (Percent)	OPEC Crude Oil Productive Capacity (Millions of Barrels per day)	Year of Initial Impact	Real Price in Year Prior to Initial Impact (1978 dollars)	Real Price in 1985 (1978 dollars)	Real Price in 1990 (1978 dollars)
Low Price	2.8%	37 MMB/D	1989	$15.00	$15.00	$20.50
Intermediate Price	3.8	37	1983	$15.00	$22.00	$38.50
High Price	4.8	37	1981	$15.00	$29.00	$55.00

Source: Division of International Analysis, Energy Information Administration, Department of Energy.

[1] The world oil prices contained in this table reflect the preliminary prices used to run the larger models and do not reflect the final prices projected by the OMS model.

Four estimates of the effects of the high world oil prices on the U.S. economy were made. Two assume high U.S. energy supplies and two assume low supplies. Each of the estimates also assumes that the effects of the high oil prices have either a relatively small or relatively large effect on foreign levels of industrial activity.

An elaborate and extended approach was used to generate the four macroeconomic estimates, reflecting changes made in assumptions during the course of the analysis. The approximate procedure used is depicted in Figure A-1.

First, PIES and other personnel estimated the effects of the high world oil prices on the U.S. energy economy without actually using the PIES model. The PIES results were implicitly based on the same macroeconomic assumptions (other than the world oil price) used to derive the effects for Scenario C.[1/] These results were then transformed as described below and, together with other assumptions (including an assumed medium adverse effect on foreign industrial activity), incorporated into the DRI model to estimate a preliminary set of effects on the U.S. national economy. The macroeconomic solution derived was then used as an assumption to generate a new (or second round) energy solution with actual use of the PIES model based on U.S. high energy supply assumptions. The PIES outputs were then used to derive a second macroeconomic

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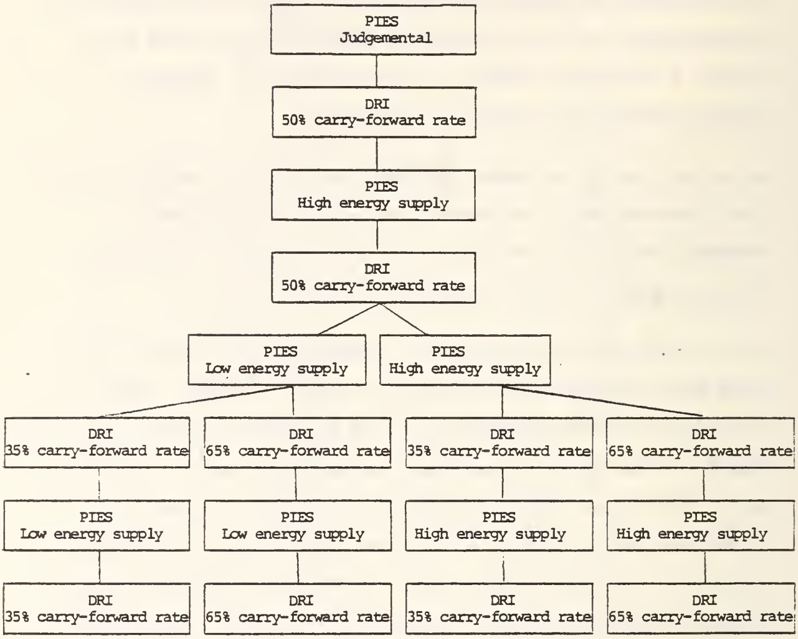
[1/] The macroeconomic assumptions were from DRI's TRENDLONG0977 solution.

Figure A-1

PIES-DRI Approximate Iterative Solution Procedures



Note: The higher the carry-forward rate the greater is the adverse impact over time of a real world oil price increase on foreign industrial activity. A 50 percent carry-forward rate is termed a "medium adverse effect" in the text.

solution. Subsequent steps in the procedure continued the process of iterating back and forth between the DRI and PIES models and incorporated changes in assumptions with respect to U.S. energy supplies and the magnitude of adverse effects on foreign economies until the four final macroeconomic impact estimates were generated. The final PIES and DRI solutions depicted in Figure A-1 were made in an attempt to obtain a greater degree of equality between the DRI values of macroeconomic variables used to drive PIES and those generated with use of the DRI model.

The PIES output variables do not correspond directly to energy-related variables in the DRI model nor are they additive components of these variables. Furthermore, the PIES information is only for 1985 and 1990, whereas the DRI model requires such information for each quarter within the forecast horizon. Consequently, transformations were made that compensated for definitional and unit of measurement differences between PIES information and the corresponding macroeconomic variables. The necessary interpolations were performed to derive quarterly values.[2/]

Additional changes were also incorporated into the DRI model. One was incorporated to reflect the effects of the rise in the real world oil price on the levels of foreign economic

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[2/] For each Macroeconomic simulation, the interpolations were between 1977 historical values and the 1985 and 1990 PIES data for that simulation.

activity since such activity affects U.S. exports. Another was incorporated to reflect the effects of the price increases on U.S. real potential GNP. These changes were made by reducing three foreign (OECD-Europe, Japan, and Canada) indexes of industrial production and a potential GNP variable below their levels in Scenario C.

The changes made to the industrial production indexes were based in part on a 1976 DRI study of the effects of a one-time increase in real OPEC prices.[3/] The percent reductions DRI made in the industrial production index for OECD-Europe for the first two years after the one-time OPEC price increase were incorporated into the DRI model after appropriately scaling them to the initial real world oil price increase in the NESS, or High Price, scenario. Industrial production indexes for Japan and Canada were reduced by the same percentages as for OECD-Europe for those two years. The percent effect of the initial real world oil price increase on foreign industrial production in any year after the first two was initially assumed to be one-half that of the immediate preceding year. This assumption was subsequently altered to 35 percent and 65 percent as indicated in Figure A-1 in order to bracket the uncertain initial parameters.

The procedure described applies to the estimation of effects on foreign industrial production indexes for a one-time increase in real world oil prices. To estimate the effects

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[3/] Data Resources, Inc., The Data Resources Review, October, 1976.

of subsequent annual increases, the entire procedure was repeated beginning with the year in which the next increase occurs. This generated several time series of industrial production index percentage reductions each of which decreased in size over time. The reductions for any given year were then summed to determine that year's percent reduction in the industrial production index. Similarly for each other year. The industrial production indexes for OECD-Europe, Japan, and Canada were then reduced in the increasing real world oil price, or NESS, scenario below the level in Scenario C by these percentages.

Potential GNP, the output that the economy can produce under conditions of full employment, is adversely affected by reductions in capital stocks. Higher real prices for imported oil adversely affect investment and, therefore, the growth in capital stock through a real balance effect. This growth may also be adversely affected if energy and capital are complementary.

U.S. potential real GNP is exogenous in the version of the DRI model used for this report. The levels of potential GNP in the NESS scenario were reduced below the levels in Scenario C. To estimate the amounts of the reductions, it was assumed that the elasticity of potential real GNP with respect to real capital stock is 0.3, roughly consistent with results from Cobb-Douglas production function studies based on actual output.[4/] Then, the percent difference between

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[4/] Paul H. Douglas, The Theory of Wages (New York: Macmillan, 1934).

the real capital stock[5/] in the NESS solution (a solution based on PIES data and adjustments to the foreign industrial production indexes) and the Scenario C solution was calculated for each year. The percent differences were then mutiplied by the elasticity value. Finally, the Scenario C potential real GNP values were reduced by the percentages derived in the preceding step to derive the new potential real GNP values for the NESS world high oil price scenario. The DRI model was then solved based on all changes previously described and the solution was compared with the Scenario C solution to determine the effects on the U.S. national economy. The procedure was repeated for each DRI model solution depicted in Figure A-1.

No variables were changed other than those previously discussed since the magnitudes of change in other variables would either have been trivial or there was little basis for determining the direction or magnitudes of change. However, sensitivity analyses were made for variables that fall into the latter category. The variables are the wholesale price index for the U.S.'s major trading partners, the U.S. dollar exchange rate, and U.S. exports to OPEC. These variables were sequentially modified in an early

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[5/] The real capital stock used was a weighted average of the effective real net capital stock of producers' durable equipment and of nonresidential structures.

stage DRI solution based on the PIES high energy supply data and a 50 percent carry-forward rate as depicted in the fourth block from the top in Figure A-1.

Three sensitivity solutions were derived by changing the variables so as to increase U.S. real GNP. Another three were derived by changing them so as to either reduce real GNP or to increase it by smaller amounts than in the first group.

Two of the six sensitivity analyses assume that foreign inflation is at rates greater than in the basic high supply 35 percent solution. The foreign wholesale price index was increased in one sensitivity analysis by amounts required to retain the same ratio of rates of increase of foreign to domestic wholesale price indexes as exists in Scenario C. The amounts were only half as great in the second sensitivity analysis. The amounts were incorporated into the analyses by increasing the constant term in the equation for the wholesale price index for the U.S.'s major trading partners.

Two sensitivity analyses were made to determine the impacts that result from changing the U.S. dollar foreign exchange rate which is exogenous in the DRI model.

To provide for possible long-term favorable effects of changes in the rate of U.S. real GNP, the dollar was appreciated from 1981 to 1990 at only half as great a compound annual rate as the approximately 0.6 percent rate in the high supply 50 percent solution. To provide for adverse effects the exchange rate was appreciated at a compound annual rate of approximately 0.9 percent. The favorable changes in the exchange rate were combined with the most favorable (or greatest) changes in foreign inflation rates for one of the sensitivity analyses, and the adverse changes in the exchange rate were combined with the less favorable (or smaller) changes in the foreign inflation rate for the other.

OPEC presently uses only part of the foreign exchange it earns from exporting petroleum to the United States to import goods and services from that country. To favorably affect U.S. real GNP, U.S. exports to OPEC were cumulatively increased, annually from 1981 through 1990, by $1 billion (in constant 1972 dollars) over the levels implicit in the high supply 50 percent solution. To estimate adverse effects U.S. exports were cumulatively decreased by $0.5 billion (in constant 1972 dollars) annually relative to the levels in that solution. Real U.S. exports to all countries were exogenized at the new levels as a proxy for the changed values of exports to OPEC. Changes in exports were combined with the favorable and unfavorable (or less favorable) changes made in the other sensitivity analyses.

Macroeconomic Impacts

This section presents the macroeconomic impacts of the higher world oil price scenario. The impacts are presented in two groups. The first is for the high and low energy supply assumptions based on low and high carry-forward rates. These four impacts are termed "basic impacts". They are measured as differentials relative to Scenario C solution results. The second is for the sensitivity analyses based on the high supply and medium (50 percent) carry-forward rate asumptions.

Basic Impacts

The impacts are estimated based upon the assumption of increasing real world oil prices, which reach about $55 per barrel in 1990. These prices and the constant $15 per barrel real price assumed for Scenario C are shown in Figure A-2. The impacts on U.S. real GNP based on the increasing prices, the high and low U.S. energy supply assumptions, and the high and low carry-forward rates are depicted in Figure A-3.

The qualitiative relationship between the four impacts on U.S. real GNP agree with theoretical expectations. The smaller the U.S. energy supply response to increasing real world oil prices the more adverse is the impact. Also, the greater the carry-forward rate the greater is the adverse impact. The impacts on real GNP, the consumer price index

FIGURE A-2

HIGH AND SCENARIO C REAL WORLD OIL PRICES, 1977–90 (in 1978 dollars per barrel)

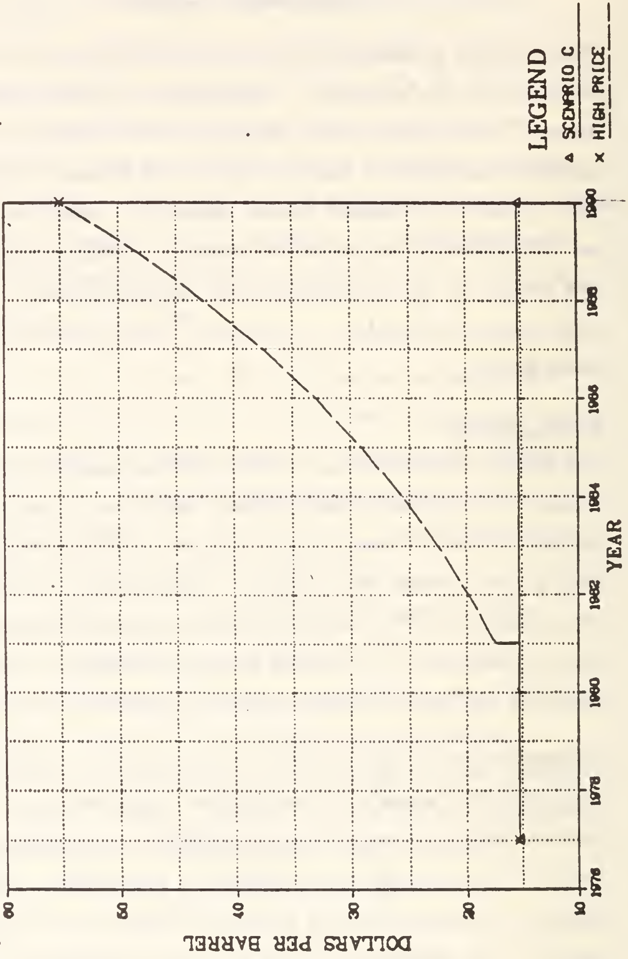
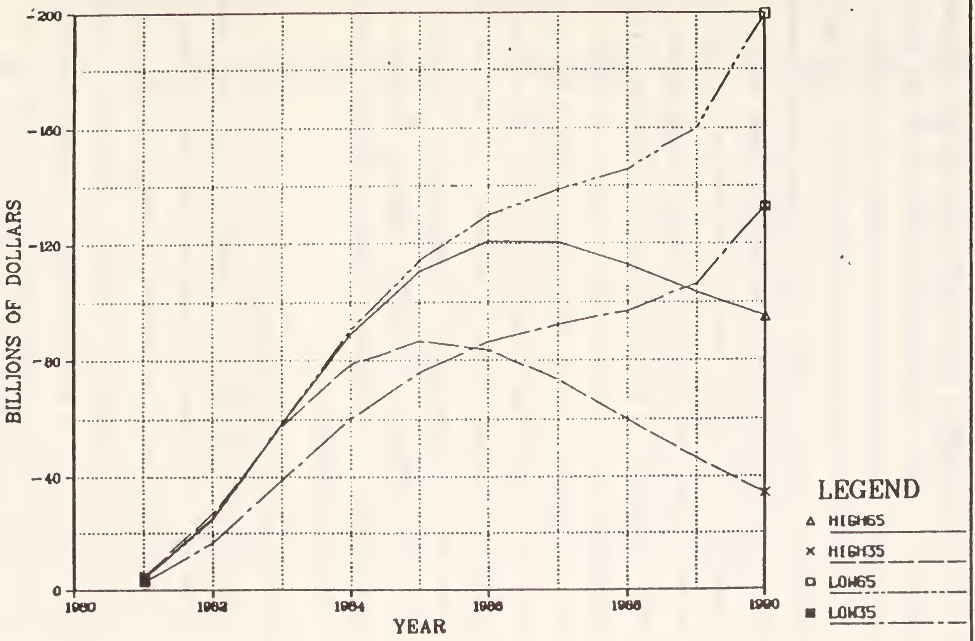


FIGURE A-3

REAL GNP IMPACTS RELATIVE TO SCENARIO C



and the unemployment rate in 1985 and 1990 are presented in Table A-2. Table A-2 shows that real GNP in the high supply 65 percent carry-forward rate solution is $74 billion (or 4.1 percent) lower relative to Scenario C in 1985 and $63 billion lower in 1990. The maximum impact, however, occurs in 1986 when GNP is $80 billion lower than in Scenario C. Initially, much of the decline in real output reflects lower investment and consumer expenditures. In 1990 consumption is down 1.9 percent, while real fixed investment is 13.6 percent lower relative to Scenario C. Real net exports, on the other hand, increase due to the reduction in petroleum imports, partially offsetting the decline in consumption and investment. In addition, the higher energy prices lead to higher general rates of inflation. Table A-2 shows that consumer prices are 1.7 percent higher in 1985 and 6.5 percent higher in 1990 relative to Scenario C.

The high supply PIES assumption coupled with only a 35 percent carry-forward rate results in substantially lower impact estimates. The effect of lowering the carry-forward rate is to lessen the impact on foreign industrial production and, therefore, to increase U.S. exports. Relative to Scenario C, real GNP in 1985 in the high supply 35 percent solution is $58 billion (or 3.2 percent) lower but in 1990 is only $23 billion lower. As in the high supply 65 percent

Table A-2

Macroeconomic Impacts of Increasing Real World Oil Prices:
High Price Solutions Relative to Scenario C Solution

Scenario	Gross National Product (Billions of 1972 dollars)		Unemployment Rate (Percent)		Consumer Price Index (1972 = 1.0)	
	1985	1990	1985	1990	1985	1990
Scenario C	1802.7	2107.4	5.0	4.6	2.735	3.382
High Supply 65%	1729.1	2044.2	6.2	4.7	2.782	3.601
Difference	-73.5	-63.2	1.3	0.2	.047	.219
% Difference	(-4.1)	(3.0)	(25.4)	(3.5)	(1.7)	(6.5)
High Supply 35%	1745.1	2084.7	5.9	4.2	2.788	3.682
Difference	-57.6	-22.7	1.0	-0.4	.053	.300
% Difference	(-3.2)	(-1.1)	(19.7)	(-9.2)	(1.9)	(8.9)
Low Supply 65%	1726.6	1974.5	6.3	6.0	2.737	3.326
Difference	-76.0	-132.9	1.4	1.5	.002	-.056
% Difference	(-4.2)	(-6.3)	(27.6)	(31.8)	(0.1)	(-1.7)
Low Supply 35%	1741.8	2021.3	6.0	5.3	2.745	3.407
Difference	-62.6	-86.1	1.1	0.7	.010	.025
% Difference	(-3.4)	(-4.1)	(21.4)	(16.0)	(0.4)	(0.7)

Note: Differences are for the high price scenario minus Scenario C. Percentage differences are these differences as a percentage of Scenario C values.

carry-forward solution both consumption and investment are lower due to the effects of the higher energy prices. However, consumption expenditures in 1990 in the high supply 35 percent carry-forward case are only 0.6 percent lower than in Scenario C.

In constrast to real GNP in the high supply solutions, where the maximum 1990 impact is $63 billion (in the high supply 65 percent solution), real GNP is substantially lower in the low supply cases. The effect of limiting the domestic supply response is to place the economy on a lower growth path. However, while the levels of real GNP are significantly lower, the magnitudes of the impact between the 65 percent and 35 percent carry-forward solutions are roughly the same for the high and low supply assumptions.

Real GNP in the low supply 65 percent carry-forward solution is $76 billion (or 4.2 percent) lower relative to Scenario C in 1985 and $133 billion (or 6.3 percent) lower in 1990. Offsetting some of the decline in investment and consumer expenditures is a slight rise in net exports in 1990. This increase in net exports reflects lower petroleum imports relative to Scenario C. The unemployment rate in 1985 is 6.3 percent and in 1990 is 6.0 percent. Prices as measured by the CPI are slightly higher relative to Scenario C through 1985 but then decline primarily due to the depressed levels of economic activity and in 1990 are 1.7 percent lower relative to Scenario C.

As expected, the adverse impact on the economy is less in the low supply 35 percent carry-forward rate solution than it is in the low supply solution with the higher carry-forward rate. Real GNP relative to Scenario C is roughly $63 billion (or 3.4 percent) lower in 1985 and $86 billion (or 4.1 percent) less in 1990. Unemployment and inflation are both higher than in Scenario C. The unemployment rate in 1985 is 6.0 percent and in 1990 5.3 percent. The CPI is 0.4 percent higher in 1985 relative to Scenario C and 0.7 percent higher in 1990.

As depicted in Figure A-1, the macroeconomic estimates are the product of sucessive iterations between the PIES system and the DRI model. The "basic impacts" presented in Table A-2 represent final iteration results. For both of the high supply scenarios, which were subsequently used in the OMS model, the final iteration impacts differ only slightly from the results obtained in the previous DRI iteration. In the high supply 65 percent case, the difference in the impact on real GNP in 1990 is only $13 billion dollars between the two solutions. In the high supply 35 percent case, the difference is only $1 billion. However, in the low supply cases, the results are further from converging to an equilibrium solution. For example, the difference in impacts for successive solutions of the low supply 65 percent scenario was approximately $47 billion dollars. Similarly, in the low supply 35 percent scenario, the effects differed by approximately $33 billion dollars between the final two DRI solutions.

The impact estimates presented in Figure A-2 and Table A-2 reflect both the assumptions upon which they are based and the procedures used to derive them. The impacts should be interpreted as simulations rather than forecasts and used with caution for several reasons.

First, the $55 per barrel 1990 world oil price used in this analysis does not necessarily reflect OPEC's most likely pricing policy. Rather, it represents only one of a number of possible future prices.

Second, the DRI macroeconomic simulation results are based to a large extent on assumed but highly uncertain estimates of the magnitude of the impact of higher oil prices on the rest of the world. Estimates of the foreign impacts were incorporated into the DRI model by sucessively reducing the foreign production indexes. However, this approach quite possibly overstates the adverse impact on foreign economies. While use of 35 percent and 65 percent carry-forward rates does provide a range in estimating the macroeconomic effects of the higher oil prices, this procedure cannot hope to capture the dynamic adjustment process that takes place in the real world.

Sensitivity Analyses

This section presents the macroeconomic impacts of sensitivity analyses based on the high supply 50 percent carry-forward rate solution depicted in Figure A-1. The assumptions underlying the analysis reflect differences in: world inflation; the dollar exchange rate; and U.S. exports to OPEC. Scenarios A through C reflect changes made to favorably impact real GNP while scenarios A' through C' reflect changes that either adversely affect real output or favorably affect GNP to a lesser extent than in Scenarios A-C. These assumptions are described in detail in the methodology section and briefly described below.

> Scenario A: The average annual rate of increase in the Wholesale Price Index for major U.S. trading partners (WPIW) was adjusted upward.
>
> Scenario B: Assumes that the dollar exchange rate (EXCH) appreciates annually at only one-half the 0.6 percent annual rate in the high supply 50 percent solution, in addition to the adjustment to WPIW.
>
> Scenario C: Incorporates the adjustments to WPIW, the exchange rate, and a cumulative annual increase of $1 billion (constant $1972 dollars) in U.S. exports (EX72).
>
> Scenario A': Assumes an upward adjustment to WPIW that is half as great as for Scenario A.
>
> Scenario B': Assumes, in addition to the preceding adjustment to WPIW, a 0.9 percent per year appreciation in the exchange rate.
>
> Scenario C': Assumes the preceding adjustment to WPIW and to the exchange rate, and $0.5 billion (real 1972 dollars) per year cumulative reduction in U.S. exports relative to the levels in the high supply 50 percent solution.

The macroeconomic results for the sensitivity analyses are presented in Table A-3. The impacts are small since the changes in assumptions were not great. The upward adjustment of $\hat{W}PIW$ in Scenario A results in a $10.5 billion (or 0.6 percent) increase in real GNP in 1990 relative to the real GNP level in the high supply 50 percent carry-forward scenario. Higher rates of inflation abroad accelerate exports of U.S. goods and services, since U.S. prices decline relative to foreign prices. The unemployment rate in 1985 is 0.2 percentage points and in 1990 0.3 percentage points lower than in the high supply 50 percent solution. The Consumer Price Index (CPI) is 0.1 percent higher in 1985 and 1.0 percent higher in 1990 reflecting the higher prices for imported goods.

Scenario B was obtained by modifying Scenario A to reflect a 0.3 percent per year depreciation in the dollar exchange rate relative to Scenario C. Dollar depreciation, like foreign wholesale price increases, accelerates U.S. exports and increases U.S. real GNP after an initial period. Real GNP is $1.7 billion higher in 1985 and $6.3 billion higher in 1990 than in Scenario A. Relative to the high supply 50 percent scenario real GNP is $12.2 billion (0.7 percent) higher in 1985 and $18.8 billion (0.9 percent) higher in 1990. The CPI is 0.1 percent higher in 1985 and 1.4 percent higher in 1990 for Scenario B relative to the high

Table A-3

Macroeconomic Estimates of Sensitivity Analysis: Sensitivity Scenarios Relative to the High Supply 50 Percent Carry-Forward Scenario

	Gross National Product (Billions of 1972 dollars)		Unemployment Rate (Percent)		Consumer Price Index (1972 = 1.00)	
	1985	1990	1985	1990	1985	1990
High Supply 50% Scenario	1745.1	2084.7	5.9	4.2	2.782	3.601
Scenario A (WPIW)	1755.6	2097.2	5.7	3.9	2.783	3.637
Difference	10.5	12.5	-0.2	-0.3	.001	.036
% Difference	(0.6)	(0.6)	(-3.7)	(-6.1)	(0.1)	(1.0)
Scenario B (WPIW + EXCH)	1757.3	2103.5	5.6	3.9	2.783	3.651
Difference	12.2	18.8	-0.3	-0.4	.001	.050
% Difference	(0.7)	(0.9)	(-4.7)	(-8.7)	(0.1)	(1.4)
Scenario C (WPIW+EXCH+EX72)[1/]	1764.3	2111.8	5.5	3.7	2.787	3.669
Difference	19.2	27.1	-0.4	-0.5	.005	.068
% Difference	(1.1)	(1.3)	(-7.0)	(-12.2)	(0.2)	(1.9)
Scenario A' (WPIW)	1750.3	2099.0	5.8	4.1	2.783	3.619
Difference	5.2	6.3	-0.1	-0.1	.001	.018
% Difference	(0.3)	(0.3)	(-1.9)	(-3.0)	(0.0)	(0.5)
Scenario B' (WPIW+EXCH)	1748.6	2086.8	5.9	4.2	2.783	3.608
Difference	3.5	2.1	-0.1	-0.0	.001	.007
% Difference	(0.2)	(0.1)	(-1.2)	(-0.6)	(0.0)	(0.2)
Scenario C' (WPIW+EXCH+EX72)	1745.2	2081.6	5.9	4.3	2.783	3.605
Difference	0.1	-2.1	-0.0	0.1	.001	.004
% Difference	(0.0)	(-0.1)	(-0.0)	(1.3)	(0.0)	(0.1)

[1/] This scenario is a sensitivity scenario and not Scenario C from the EIA Annual Report.

supply 50 percent scenario, reflecting the inflationary effects of higher levels of U.S. economic activity and higher import prices.

In Scenario C, real exports were cumulatively increased by $1 billion per year to reflect accelerated recycling of OPEC oil revenues. The roughly $10 billion exogenous increase in real exports by 1990 does not, however, translate into a dollar for dollar increase in real GNP, at least in part because of the impact of the inflationary effects it induces. Nevertheless, the increased exports raise real GNP relative to Scenario B by $7.6 billion in 1985 and $8.1 billion in 1990. The increase in output lowers the unemployment rate and raises the price level. The CPI is 0.2 percent higher in 1985 and 1.3 percent higher in 1990 relative to the high supply 50 percent scenario.

The impacts in Scenarios A' through C' reflect less favorable assumptions with respect to foreign inflation, the dollar exchange rate, and real exports than in the preceding scenarios. In Scenario A', the WPIW is adjusted upward as in Scenario A but to a lesser extent. Real GNP increases in Scenario A' relative to the high supply 50 percent scenario but the increase is substantially less than in Scenario A. Real GNP is $3.6 billion higher in 1985 and $6.2 billion higher in 1990. Similarly, the price levels are marginally higher in Scenario A' than in the high supply 50 percent scenario but, again, less than in Scenario A. In 1985 the CPI is virtually unchanged relative to the high supply 50 percent scenario and in 1990 is only 0.5 percent higher.

Scenario B' includes the adjustment to WPIW and assumes a 0.3 percent per year appreciation in the foreign exchange rate relative to the high supply 50 percent scenario. The appreciation increases U.S. export prices relative to U.S. import prices. U.S. exports decrease, imports increase, and real GNP decreases relative to Scenario A'. Real GNP is nevertheless $3.5 billion higher in 1985, and $2.1 billion higher in 1990 relative to the high supply 50 percent scenario because of the favorable effect on GNP from higher wholesale prices (WPIW) abroad. While the general price level is slightly higher relative to the high supply 50 percent scenario, prices are nevertheless lower than in Scenario A' in 1990.

Scenario C' includes both the upward adjustment to WPIW and the appreciation of the exchange rate, as well as a $0.5 billion per year cumulative reduction in real exports relative to the high supply 50 percent scenario. The reduction in exports reflects a pessimistic assumption about OPEC's future absorptive capacity. As a result of the exogenous reduction in U.S. exports, real GNP is less than in Scenario B' (by $ 3 billion in 1990), but the unemployment rate and the general price level change only trivially.

The sensitivity impact estimates indicate that the effects of altering foreign prices, exchange rates and U.S. exports are small for the variables considered. The effects are small since the changes in assumptions are also small. But the magnitudes of changes made were not entirely aribitrary and may be considered reasonable in light of expected future developments.

Appendix B

The Methodology of the Oil Market Simulation Model

This analysis of world oil prices was completed with a parametric representation of the world oil market known as the Oil Market Simulation Model (OMS). This model is a semi-reduced form representation of the International Energy Evaluation System (IEES), the Project Independence Evaluation System (PIES), and the DRI macro model. The OMS model is calibrated to PIES and IEES by first inputing a series of reference supply and demand points taken from the PIES and IEES Mid-Range cases assuming constant world oil prices. Then given an approximation of the PIES and IEES demand and supply elasticities, the model is iterated for any particular scenario until an energy market equilibrium is reached. In addition the OMS model includes an economic feedback elasticity parameter estimated from the DRI model simulations. The feedback elasticity is defined as the elasticity of GNP with respect to the price of oil. The effect of this elasticity is to reduce the demand for oil through reductions in the rate of economic growth.

The reference demand paths (at constant oil prices) for the High and Low economic growth cases were derived from special runs of the PIES model, for the United States, and an approximation of the IEES results for the remaining regions of the world. The non-OPEC supply paths are assumed to vary as a function of price but not across scenarios since production is, for all intents and purposes, invariant with respect to the rate of economic growth.

The OMS model consists of two equations for each world region defining the supply and demand paths over the forecast period evaluated at constant world oil prices. The model works by solving for a price of oil which will then balance supply and demand under alternative estimates of OPEC production capacity. The initial demand level is determined by the rate of economic growth and the price of world oil while non-OPEC supplies are determined strictly by the price of oil. The non-OPEC supplies are added to the assumed level of OPEC production to derive total supply. Then, given the desired demand and available supplies, the market clearing price is calculated.

In order to understand the operation of the model, it is instructive to follow the adjustment mechanism when supplies and demands are not in equilbrium. When demand exceeds supply, consumers bid up the price of oil. The movement to higher prices causes three adjustments to take place simultaneously. These are:

- The direct impact of higher oil prices on oil demand causes the quantity demanded to decrease and an increase in the demand for alternative energy forms;
- A decrease in the rate of growth of real GNP due to economic feedback causes total energy and oil demands to decrease; and,
- An increase in the supply of non-OPEC oil takes place in response to increasing prices.

Final equilibrium is then reached when supply and demand are equalized. All three of these adjustments by consumers and producers grow over time as energy saving capital adjustments are implemented and efficiency increases through stock changes, and new wells and other advanced production techniques are introduced. Therefore, the OMS model is specified as being dynamic with the appropriate demand and supply elasticities increasing over time with the size of the elasticities conditioned by the supply of alternative energy forms and their price reactions.

The OMS is a regional model consisting of seven regions. These regions are designed to encompass the major producing and consuming regions of the world. A summary of the regions is presented in Table B-1.

As previously mentioned, the OMS model consists of supply and demand equations for each region. The model works by determining the market clearing price given some reference supply and demand path and an OPEC production rate. Demand in the current time period is expressed as a function of last periods demand, price, and the GNP feedback effect or:

$$(1)\ \text{Demand}(t) = \text{Demand}(t-1)_i^{\alpha_D}\ \ \text{Price}(t)^{\beta_D}\ \ \text{GNP}(t)_i^{\gamma_D}$$

where i is an index of the region. Demand in the current period is specified so that when summed over all demand regions (i),

Table B-1

OIL MARKET SIMULATION MODEL (OMS) DEMAND AND SUPPLY REGIONS

Regions

United States

Canada

Japan

Europe

LDC's (includes Australia/New Zealand and other developed countries)

OPEC

Communist Countries (net exports to free world) it is set equal to the sum of non-OPEC supplies plus the OPEC production level specified at the outset of the analysis or:

$$(2)\quad \sum_{i=1}^{n} \overset{*}{\text{Demand}(t)}_{i} = \sum_{j=1}^{m} \text{Supply}(t) + \text{OPEC } \overset{*}{\text{Supply}(t)}$$

where n = total number of demand regions,

m = total number of non-OPEC supply regions, and

* = denotes demand and supply levels as opposed to percent differences.

Non-OPEC supply in year t is expressed as a function of supply in the previous period and price lagged two years or:

$$(3)\quad \text{Supply}(t)_{j} = \text{Supply}(t-1)_{j}^{\alpha_S} \quad \text{Price}(t-2)^{\beta_S}$$

where j represents the non-OPEC supply regions. It is critical to the understanding of the analysis to note that the terms demand, supply, and price in equations (1) and (3) are expressed relative to a Reference case (exogenously determined by the rate of economic growth). For example, the term Demand(t) equals the percent difference between the Reference case demand and final demand or:

$$(4)\quad \text{Demand}(t) = \frac{\text{Demand }(t)}{\text{Demand }(t)_{\text{REF}}}$$

where the REF stands for the Reference case demands.

The GNP term deserves special explanation since it does not represent a growth rate in GNP but represents the change in GNP relative to the Reference case which is determined by the change in price or:

$$(5) \quad \text{GNP}\ (t) = \frac{\text{GNP}\ (t)}{\text{GNP}\ (t)_{\text{REF}}} = \left(\frac{\text{Price}(t)}{\text{Price}(t)_{\text{REF}}}\right)^{\varepsilon_\gamma}$$

where ε_γ is the feedback elasticity or the elasticity of GNP with respect to a change in oil prices.

The OMS model represents an approximation of the PIES and IEES models and as such, the determination of the parameter values β_D, β_S, α_D, α_S and γ_D are critical to the analysis. The price term exponents β_D and β_S represent the initial responsiveness of demand and supply respectively, to a price change, while the exponents, α_D and α_S, of the lagged demand and supply quantities control the speed at which the total price response cumulates over time. The exponent γ_D measures the initial response of demand to a change in the level of GNP relative to the reference GNP and is referred to below as the income response parameter.

Since the PIES and IEES models yield full energy market equilibrium solutions, the calibration of OMS to these models yield parameter values which are to be interpreted as system equilibrium response parameters. In other words, the system equilibrium oil response depends not only upon the price of oil, but also on the prices of alternatiive energy forms.

The values of the supply, demand, and lag parameters are calculated from the PIES and IEES scenarios. The Reference demand and supply values are taken directly from the PIES and IEES results while the parameter values are derived from three sets of runs. The runs used in the calculation of the basic parameters are a Reference constant oil price run, a medium price run with price increasing 5 percent per year starting in 1981, a high price run with prices increasing 14 percent per year starting in 1981, and a high price run with the high economic feedback elasticities. The level price and 5 percent price increase scenarios are used to estimate price elasticities for sets of supply and demand curves used for low price increase cases. A second set of price elasticities are calculated using the level price and 14 percent increase runs. This second calculation is used to define a new set of supply and demand curves which are assumed to be effective for scenarios resulting in relatively high world oil prices. These two sets of supply and demand curves are used to capture certain non-linearies contained in the various price levels.

The model is calibrated using a three step process. These steps are:

1. The underlying PIES and IEES demand models were used to derive the response coefficients α_D by examining the effect of a substained small increment in price over the forecast period. Similarly, the dynamics of the Oil and Gas Supply Model were examined to determine values for the response coefficients α_s.

2. The price parameter values β_D, β_s are then calibrated in OMS to reproduce the five percent price increase demand and supply projections for both the 81/85 and 86/90 time periods. The speed of response coefficients α are assumed to remain constant across price levels.

3. Step 2 is repeated to calibrate β_D, β_s for the 14 percent price increase. The income response parameter γ_D is calibrated for only the 14 percent price increase and high economic feedback case.

The calibration procedure is designed to use the information in the underlying demand and supply models to capture the non-symmetrical price response dynamics under a fairly wide range of price levels which vary from constant price levels to prices increasing by 14 percent per annum.

The parameters for both the low 5 percent price increase and the 14 percent price increase are as summarized in Table B-2. Given these parameter values, the 5 percent price increase values are used in the simulations of the low growth case while the 14 percent price increase parameters are used in the moderate growth simulations. This selection of parameters was based upon preliminary runs of the model which indicated that the resultant prices would be in the range of these two price calibrations.

Table B-2

OMS PARAMETER VALUES 1/

REGION	Price Elasticity (β)				Lag Exponent (α)	Income Elasticity (γ)	
	5% Price Rise		14% Price Rise				
	(81/85)	(86/90)	(81/85)	(86/90)	(81/90)	(81/85)	(86/90)
Demand							
U.S.	-.08	-.12	-.10	-.12	.50	1.06	.64
Canada	-.23	-.32	-.18	-.21	.46	.72	.68
Japan	-.22	-.28	-.18	-.16	.40	.76	.83
Europe	-.13	-.17	-.11	-.13	.56	.76	.65
Other 2/	-.07	-.07	-.07	-.07	.59	.43	.43
Supply							
All Non-OPEC Regions	.10	.10	.08	.07	.95	-	-

1/ All parameters represent one year price and income responses.

2/ Estimates for this region are a weighted average of high, medium, and low income IBRD country group parameter values and are assumed to be constant across the various price levels.

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APPENDIX III

Summary of Energy Forecasts; Domestic U.S. and World Energy Projections

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ENERGY POLICY PROJECT OF THE FORD FOUNDATION "A TIME TO CHOOSE," CAMBRIDGE, MASS., 1974

DEMAND

GNP growth rates are projected at 3.6 percent per year from 1975–85, and 3.3 percent per year for the period 1985–2000.

Three energy demand scenarios were developed: A historical growth scenario, a technical fix scenario, and a zero growth scenario.

The historical energy growth rate of 3.4 percent per year was based on the average energy growth rates between 1950 and 1973. The historical growth rate was assumed as the base case in many Government and industry forecasts made at the time the Ford Foundation study was conducted. This growth rate, using 1973 as the base year, was projected to result in a total primary energy demand of 116.1 quads in 1985 (about 58 million bbl/d oil equivalent) and 186.7 quads by the year 2000 (about 93 million bbl/d oil equivalent). Crude oil prices in the range of $7 to $8 (1978 dollars) between 1985 and 2000 were said to be consistent with historical growth rates.

The technical fix scenario was an attempt to anticipate the results if long-term energy prices and Government policies were to encourage greater efficiency in energy consumption. This would not result in lowering living standards.

Annual energy consumption under this scenario would average 1.9 percent per year between 1973 and the end of the century. From 1975–85 energy growth rates would be 2.1 annually; after 1985, energy growth rates would go down to 1.2 percent per year. Better insulation, better auto fuel economy, more efficient energy use in the industrial sectors and various other conservation measures would bring about the lower energy growth rates.

Under the technical fix scenario, using 1973 as the base year, energy consumption would rise to 91.3 quads in 1985 (about 45.5 million bbl/d) and 124 quads by the year 2000 (about 62 million bbl/d oil equivalent).

THE ZERO GROWTH SCENARIO

This scenario does call for significant changes in life styles, with greater emphasis on services which generally require much less energy per dollar than heavy industrial production or primary metals processing, whose growth would be deemphasized. Durability of goods would be emphasized in this scenario.

Zero energy growth would not be possible until after the middle 1980's. The principal reason for striving for zero energy growth rates is protection of the environment.

Total energy consumption under this scenario—using 1973 as the base year—would result in total primary energy consumption of 88.1 quads in 1985 (about 44 million bond oil equivalent) and 100 quads by the end of the century (about 50 million bbl/d oil equivalent).

On the supply side of the energy equation, this study provides energy balances for the three scenarios discussed above shown in tables 1, 2, and 3.

In view of recent Government and industry demand estimates, the demand part of the Ford Foundation study is no longer as far removed from the main stream as it was in 1974. In fact, the technical fix scenario projecting total energy demand in 1985 at slightly over 90 quads, is very much in line with the national energy plan and several recent industry forecasts.

On the supply side the study is quite different from more recent studies. The principal difference lies in projections of oil and natural gas production. The technical fix scenario estimates U.S. oil production to rise to 14.2 million bbl/d in 1985 and 17.0 million bbl/d by the year 2000. Natural gas production would increase to 25.7 tcf in 1985 and 31 tcf by the year 2000.

The Ford Foundation study based its oil and gas supply forecasts on the high resources estimates generally used by energy forecasters prior to 1975. In 1975, the U.S. Geological Survey released new oil and gas resources estimates for the United States, which were several orders of magnitude below the earlier USGS estimates by McKelvey, Zapp, and others.

If the Ford Foundation study would have had access to the USGS study, oil and gas production estimates for 1985 and 2000 would probably have been substantially lower. It is interesting to speculate with the lower liquid hydrocarbon resources estimates, because both coal (conventional) and nuclear energy were not considered to be preferable sources of future energy supply (environmental concerns).

TABLE 1.—HISTORICAL GROWTH ENERGY SUPPLIES

[In quadrillion Btu's]

	Actual 1973	Domestic oil and gas		High nuclear		High imports	
		1985	2000	1985	2000	1985	2000
Domestic oil	22	32	40	32	34	27	27
Shale oil	0	2	10	2	10	1	2
Synthetic liquids from coal	0	1	5	1	5	0	3
Imported oil	12	10	9	10	9	22	32
Nuclear	1	10	40	12	50	10	40
Coal (except synthetics)	13	25	33	23	33	20	38
Domestic gas	23	29	37	29	31	26	27
Synthetic gas from coal	0	1	3	1	3	1	3
Imported gas	1	1	0	1	2	4	5
Hydro	3	3	4	3	4	3	4
Geothermal	0	1	2	1	2	1	2
Other	0	0	1	0	1	0	1
Conversion losses:							
From coal synthetics	0	1	3	1	4	0	3
Total	75	116	187	116	188	115	187

TABLE 2.—TECHNICAL FIX ENERGY SUPPLIES

[In quadrillion Btu's]

	Actual 1973	Self-sufficiency		Environmental Protection	
		1985	2000	1985	2000
Domestic oil	22	30	36	29	35
Shale oil	0	1	3	0	1
Synthetic liquids from coal	0	0	3	0	3
Imported oil	12	6	6	12	12
Nuclear	1	8	11	5	3
Coal (except synthetics)	13	16	22	14	22
Domestic gas	23	27	32	26	32
Synthetic gas from coal	0	0	1	0	0
Imported gas	1	1	0	2	4
Hydro	3	3	4	3	4
Geothermal	0	0	2	0	2
Other	0	0	2	1	4
Conversion losses from coal synthetics	0	0	2	0	1
Total	75	92	124	92	123

TABLE 3.—ZEG ENERGY SUPPLIES

[In quadrillion Btu's]

	Actual 1973	1985	2000
Domestic oil	22	28	30
Shale oil	0	0	0
Synthetic liquids from coal	0	0	0
Imported oil	12	9	9
Nuclear	1	5	3
Coal (except synthetics)	13	14	18
Domestic gas	23	25	25
Synthetic gas from coal	0	0	0
Imported gas	1	2	4
Hydro	3	3	4
Geothermal	0	1	2
Other	0	1	5
Conversion losses from coal synthetics	0	0	0
Total	75	88	100

Federal Energy Administration, Project Independence, Washington, D.C., November 1974

Project Independence was initially conceived by President Nixon in November 1973, following the beginning of the Arab oil embargo. The President's proposal led to the creation of the Federal Energy Administration in the spring of 1974. The first priority assigned to FEA by the President was to work with other Government agencies on a comprehensive plan for achieving the goals of Project Independence; that is, the capacity to bring about energy self-sufficiency by 1980. President Ford changed the date for energy independence to 1985 after the Project Independence blueprint had been completed by FEA in November 1974.

While the study produced several energy demand and supply scenarios, the two most frequently quoted are the $7 and $11 oil import scenarios. The study concluded that if the price of domestic oil would be allowed to rise to $11 per barrel, and the Government would accelerate leasing of Federal offshore lands and the naval petroleum reserves, the Nation could be energy independent by 1985. Assuming no accelerated leasing of Federal lands for oil and gas and a somewhat less aggressive nuclear power program, oil imports could still be limited to about 3.0 million bbl/d by 1985. Emergency storage of oil and standby authority to reduce consumption could limit vulnerability to another oil embargo to a very insignificant degree.

TABLE 1.—DOMESTIC FUEL CONSUMPTION BY SOURCE, 1985

[In quads]

	$7 oil		$11 oil	
	Base case	Accelerated development	Base case	Accelerated development
Coal	19.1	17.7	22.9	20.7
Oil	23.1	30.5	31.3	38.0
Natural gas	23.9	24.7	24.8	25.5
Hydro/Geothermal	2.9	4.8	4.8	4.8
Nuclear	12.5	14.7	12.5	14.7
Synfuels				.4
Imported oil	24.8	17.1	6.5	0

Source: Federal Energy Administration, "Project Independence," Washington, D.C., November 1974, p. 46.

Domestic supply data in table 1 were based on the following assumptions: in the business-as-usual (BAU) scenario, FEA assumed a moderate OCS leasing program (1 to 3 million acres per year) and Prudhoe Bay developed with one pipeline; gradual deregulation of new natural gas, and construction of LNG facilities in Alaska; some Federal coal land leasing, and phased implementation of the Clean Air Act with installation of effective stack gas control equipment; moderate strip mining legislation; no change in licensing or regulations of nuclear power, and construction of additional uranium enrichment and reprocessing capacity; no change in synthetic fuel and shale oil policies;

continued R. & D. funding of geothermal and solar power; oil was priced at $7 and $11 per barrel. The accelerated scenario would at the same prices of oil further require: an expanded leasing program (more than 3 million acres per year of OCS lands); development of Naval Petroleum Reserve No. 4; additional gas pipelines in Alaska, and some gas produced from tight formations; additional leasing of Federal lands for coal development, and opening of large coal mines; streamlined siting and licensing of nuclear powerplants to reduce leadtimes; streamlined licensing and siting of synfuel development; financial incentives to build such plants, and increased water availability for synfuels development; additional leasing of Federal lands or shale oil development; financial incentives for such developments; increased water availability to develop shale, and modification of Colorado air quality standards (most shale is located in Colorado); leasing of Federal lands for geothermal development, additional financial incentives, and streamlining licensing and regulatory procedures for geothermal developments; and, additional R. & D. and financial incentives for the development of solar energy.

Projections for nuclear power and coal utilization in the Project Independence report were within the same range of most other energy studies published at that time, but from the outset many critics could not accept the high figures for domestic oil and natural gas supply. In particular, the accelerated development scenario at $11 per barrel (world market price of oil) quoted very high domestic oil production for 1985. In order to achieve an oil production of between 31.3 and 38.0 quadrillion BTU's (13.1 to 16.5 million bbl/d) at $11 per barrel, total domestic oil production by 1985 was supposed to come from the following sources:

TABLE 2.—SOURCES OF DOMESTIC U.S. OIL PRODUCTION BY 1985

	$7 per barrel		$11 per barrel	
	BAU	AD	BAU	AD
Lower 48 States	4.2	4.3	7.4	6.3
Alaska North Slope	2.5	2.5	2.5	2.5
Alaska other	.1	.1	.5	.8
Alaska NPR No. 4	.0	2.0	.0	2.0
OCS	2.1	3.6	2.1	3.6
Shale oil	.3	.3	.3	1.0
Tar sands	.0	.0	.1	
Total	9.2	12.8	13.1	[1] 16.5

[1] This total could be 17,200,000 bbl/d, but only 16,500,000 bbl/d could be consumed.

Source: Federal Energy Administration, "Project Independence." report, op. cit., p. 47.

Critics maintained from the outset that the accelerated development case at $11 per barrel was unrealistically high, not only in view of physical constraints on the resource base, but also because of development leadtimes, assumptions about technical developments, and price elasticity of supply.

Similar optimistic assumption underlie the data for future natural gas production, estimated in PIB at between 22.6 and 25.8 trillion cubic feet per year by 1985. In fact, natural gas production in the United States peaked at about 22.5 trillion cubic feet per year in 1973, and has declined ever since. There is no evidence that this trend can be reserved substantially for years to come, and some experts believe that the United States reached its final natural gas production peak in 1973.

The Federal Energy Administration updated PIB in 1976. The revised study was issued under the new title: "National Energy Outlook 1976." The basic demand and supply analysis had not changed much.

TABLE 3.—DOMESTIC ENERGY SUPPLY, 1985

[Neo 1976]

	Reference case		Accelerated development	
	$13 per barrel	$16 per barrel	$13 per barrel	$16 per barrel
Coal (million tons)	1,039	1,085	2,010	2,020
Oil (million barrels per day)	13.9	14.9	16.0	17.2
Natural gas (thousand cubic feet/year)	22.27	22.65	26.2	26.7
Nuclear (quads)	8.7	8.7	8.7	8.7
Geothermal, hydro, and solar (quads)	3.9	3.9	4.4	4.4

Source Federal Energy Administration, "National Energy Outlook 1976," Washington, D.C., February 1976, pp. G-2 and G-6.

The assumptions made for the BAU supply analysis are almost indentical to the BAU case in PIB, and the accelerated development case shows the effects of an agressive, but achievable effort—according to FEA—to increase domestic energy resource development. The accelerated development case together with certain conservation actions could reduce U.S. oil imports to between 0 and 1.4 million barrels per day in PIB and between 1.4 and 5.9 million barrels per day in PIB and between 1.4 and 5.9 million barrels per day in PIB and between 1.4 and 5.9 million barrels per day in NEO 1976. While FEA analysts believed that the accelerated development case was achievable, the reference scenario, leading to oil imports of 5.9 million barrels per day is the scenario closest to what FEA believed attainable by 1985.

Oil and natural gas production projections in the NEO 1976 were still higher than most private estimates. The differences in projections are not so much due to differences in resources projections, but are primarily based on different assumptions concerning development lead times, price elasticity of supply and more optimistic political assumptions related to Federal leasing policy of the Outer Continental Shelf and other Federal lands.

The 1977 issue of the National Energy Outlook has never been published, but available drafts indicated that the FEA had significantly reduced its oil and natural gas production estimates for the next decade through 1985. In the area of supply, FEA had entered the arena of the more conservative forecasters, and some oil companies maintained that NEO 1977 was too conservative on oil and especially on natural gas projections.

CONGRESSIONAL RESEARCH SERVICE 1975 STUDY: TOWARDS PROJECT INTERDEPENDENCE: ENERGY IN THE COMING DECADE

The study assumed that energy growth rates were likely to increase by 2.5 to 3.1 percent annually. The study assumed that oil would be decontrolled by 1977, and that there would be some decontrol of natural gas during the period studied. Also, Naval Petroleum Reserve

No. 4 would be developed and a second Arctic pipeline will be required by 1985; OCS leasing would be accelerated, and lead times between exploration and development would be shortened. There is no capital shortage, and the President's—Ford—multibillion dollar synfuels program would be implemented.

The author of the study did not develop his own oil and gas supply model, but relied on a consensus view, after reviewing a large number of Government corporate and other energy demand and supply studies.

The following projections were made for domestic oil supply: 11.0 million barrels per day in 1980 and 12.0 million barrels per day by 1985. Of the total 1985 figure, 4.9 million barrels per day would come from the lower 48 States onshore; 0.6 million barrels per day from tertiary recovery; 2.2 million barrels per day from Alaska; and, 3.8 million barrels per day from offshore areas.

Natural gas production projections were as follows: total natural gas supply by 1985 was estimated at 19 trillion cubic feet. Of this, 2 trillion cubic feet would come from Alaska and syngas—1.5 trillion cubic feet Alaska and 0.5 trillion cubic feet syngas. The remaining 17 trillion cubic feet would have to come from the lower 48 States onshore and offshore. Constraints on the construction of a natural gas pipeline in Alaska, slower Outer Continental Shelf leasing developments, and reduced expectations for synfuel developments may result in lower oil and gas production than projected in the study. Even with the cautiously optimistic supply projections in this study, oil imports would grow to between 9.0 and 10.4 million barrels per day respectively in the 2.8 and 3.1 percent annual energy growth rates' scenarios.

The study concluded that short of dramatic measures to curb domestic demand and increase domestic supplies of energy, the gap between energy demand and supply in the United States would continue to grow indefinitely. Even if proper conservation measures and supply-stimulating actions were taken, oil imports would still increase steadily until at least the middle 1980's, when imports could be stablized for a decade or more at a level of 10 million barrels per day or less.

TABLE 4.—FORECASTS OF MAJOR SOURCES OF ENERGY SUPPLY IN THE UNITED STATES

[In millions of barrels per day oil equivalent]

Source	1973	1977	1980	1985
Oil (crude and natural gas liquids)	10.1	[1] 10.0	11.0	12.0
Natural gas (including syngas)	10.6	8.9	8.0	8.9
Coal	6.4	7.4	8.2	9.7
Nuclear	.4	1.6	2.4	5.3
Hydro	1.4	1.4	1.5	1.7
Geothermal	Negl	Negl	.1	.2
Shale oil	0	0	.2	.5
Other (solid waste, syncrude, solar)	0	0	.2	.4
Total	28.9	29.3	31.6	38.7

[1] Supply estimate assumes complete oil decontrol. Decontrol of old oil could add as much as 300,000 bbl/d according to FEA estimates.

Note: 1 trillion ft^3/yr equals 472,000 bbl/d; 1,000,000 tons of coal equals 3,000,000 to 4,000,000 bbl of oil; 1 GWe equals 28,000 bbl/d.

BUREAU OF MINES: U.S. ENERGY THROUGH THE YEAR 2000, DECEMBER 1975

The oil and gas resource base of the BOM study is based on U.S. Geological Survey circular 725. Energy growth rates are projected at somewhat higher levels than the FEA studies. BOM projects GNP to grow at an annual average of 4.9 percent for the rest of this decade; at 3.3 percent for the next decade. Energy growth rates are expected to grow 3 percent p.a. from 1974–80; 3.5 percent from 1980–85; and, 3.1 percent from 1985–2000. Total primary demand for energy is estimated to rise from about 73 quads in 1974 to 87 quads in 1980; 103.5 quads in 1985; and, 163 quads by the end of the century.

OIL

The BOM study projects total U.S. oil production—conventional oil—to rise from 10.8 million bbl/d in 1974 to 11.9 million bbl/d in 1980; 14.5 million bbl/d in 1985; and decline to 13.6 million bbl/d by the year 2000.

The increased production will come largely from Alaska, where production is projected to rise to 2 million bbl/d in 1980; 4 million bbl/d in 1985; and then decline to 3.8 million bbl/d by the year 2000. Beyond 1980 synthetic liquids are expected to begin to contribute larger quantities.

NATURAL GAS

Natural gas production is forecasted to decline to 19 TCF in 1980, 18.7 TCF in 1985 (including 1.5 TCF of Alaskan gas), and 16.5 TCF in 1990. Synthetic gas would increase from zero through the early 1980's, to 1.5 TCF in 1985, and 2.9 TCF by 1990. Pipeline gas imports were estimated to decrease from 0.9 TCF in 1974 to 0.8 TCF in 1980 and 0.7 TCF in 1985. Thereafter, pipeline gas imports would grow again to 1 TCF in 1990. Liquid natural gas imports would reach 0.3 TCF in 1980; 0.7 TCF in 1985; and, 1.5 TCF by 1990.

Hence, in order to maintain gas consumption at 1974 levels through the year 2000, the country would have to rely increasingly on Alaskan gas, synthetic gas, and LNG imports.

COAL

The BOM projects total domestic coal demand to grow from 557 million tons in 1974 to 736 million tons in 1980; 923 million tons in 1985; and 1,560 million tons by the year 2000.

Export demand would add 60 million tons in 1974; 70 million tons in 1980; 75 million tons in 1985; and 100 million tons by the year 2000.

The BOM study assumes that SO_2 emission problems would be solved by the 1980–85 period, and from that period on coal use would be environmentally acceptable. It was also assumed that strip mining of coal would remain competitive with other energy sources. The expansion of coal use would be almost exclusively in the electric utility sector, with minor expansion in the industrial sector of the economy.

NUCLEAR POWER

Installed generating capacity is projected to increase from approximately 32 gigawatts in 1974 to 75 gigawatts in 1980; 200 gigawatts in 1985; and, 900 gigawatts by the year 2000.

Energy inputs for the same years were projected at 1.2 quadrillion Btu in 1974; 4.6 quads in 1980; 11.6 quads in 1985; and, 46 quads by the year 2000. For the period from 1980–2000, the capacity factor was put at 0.65.

OTHER SOURCES OF ENERGY

Hydropower and geothermal energy contributed 3 quads to U.S. energy supply in 1974. These sources are projected to contribute 3.8 quads in 1980; 3.85 quads in 1985; and, 6 quads by the year 2000.

Oil shale is projected to produce 157,000 b/d in 1985 and just over 1 million b/d by the end of the century. Synthetic gas is estimated to supply 0.1 trillion cubic feet in 1980; 0.45 TCF in 1985; and, 4.2 TCF by the year 2000. Synthetic liquids are projected to supply 110,000 b/d in 1985 and 1 million b/d by the end of the century.

TABLE 1.—GROSS AND NET ENERGY INPUTS TO THE U.S. ECONOMY, 1974–2000

[In trillion Btu's]

	1974	1980	1985	2000
Net energy consumption:				
Nonfuel uses [1]	5,159	5,630	5,650	7,810
Percent of total	7.1	5.9	5.5	4.8
3-sector energy uses [2]	54,696	63,730	71,840	102,420
Percent of total	74.8	73.1	69.4	62.7
Total net energy	59,855	68,860	77,490	110,230
Percent of total energy use	81.9	79.0	74.9	67.5
Conversion losses: [3]				
Electrical sectors	13,265	18,250	25,580	49,030
Percent of total	18.1	21.0	24.7	30.0
Synthetic gas sector	0	30	210	1,800
Percent of total	0	------------	.2	1.1
Synthetic liquids sector	0	0	260	2,370
Percent of total	0	0	.2	1.4
Total conversion losses	13,265	18,280	26,050	53,200
Percent of total energy use	18.1	21.0	25.1	32.5
Total gross energy inputs	73,121	87,140	103,540	163,430

[1] This refers primarily to asphalt and road oil in the residential and commercial sector, chemical feedstocks in the industrial sector, and lubes and greases in the transportation sector.

[2] The 3 sectors are the residential and commercial, industrial, and transportation. These are the end-users of energy in the economy.

[3] Conversion losses refer to those losses caused by converting a primary energy source to a secondary energy source.

TABLE 2.—U.S. GROSS CONSUMPTION OF ENERGY RESOURCES BY MAJOR SOURCES, 1974 PRELIMINARY AND PROJECTED TO THE YEAR 2000

	1974	1980	1985	2000
Petroleum:				
Million barrels	6,080.8	7,433	8,265	9,274
Trillion Btu	33,490	41,040	45,630	51,200
Percent of total gross inputs	45.8	47.1	44.1	31.3
Natural gas:				
Billion cubic feet	21,780	19,900	19,510	19,030
Trillion Btu	22,237	20,600	20,100	19,600
Percent of total gross imputs	30.5	23.6	19.4	12.0
Coal (all ranks):[1]				
Million short tons	556.5	736	923	1,560
Trillion Btu	13,169	17,150	21,250	34,750
Percent of total gross inputs	18.0	19.7	20.5	21.3
Oil shale:				
Million barrels			157	1,040
Trillion Btu			870	5,730
Percent of total gross inputs			.8	3.5
Hydropower and geothermal:				
Billion kWh	291	343	391	605
Trillion Btu	3,052	3,800	3,850	6,070
Percent of total gross inputs	4.1	4.4	3.8	3.7
Nuclear power:				
Billion kWh	110	427	1,139	5,120
Trillion Btu	1,173	4,550	11,840	46,080
Percent of total gross inputs	1.6	5.2	11.4	28.2
Total gross energy input (trillion Btu)	73,121	87,140	103,540	163,430

[1] Does not include coal exports.

TABLE 3.—ESTIMATED LIQUID HYDROCARBON SUPPLY SCHEDULE, 1974 PRELIMINARY AND PROJECTED TO THE YEAR 2000

	1974	1980	1985	2000
Total supply:				
Million barrels	6,080.8	7,433	8,375	10,274
Million barrels per day	16.7	20.4	22.9	28.1
Trillion Btu	33,490	41,040	46,240	56,700
Domestic supply:				
Lower 48 States[1]				
Million barrels	3,925.7	3,625	3,847	3,577
Million barrels per day	10.8	9.9	10.5	9.8
Trillion Btu	21,058	20,010	21,240	19,760
Alaska:[1]				
Million barrels		730	1,460	1,387
Million barrels per day		2.0	4.0	3.8
Trillion Btu		4,030	8,060	7,660
Synthetic liquids:[2]				
Million barrels			110	1,000
Million barrels per day			.3	2.7
Trillion Btu			610	5,500
Total domestic supply:				
Million barrels	3,925.7	4,355	5,417	5,964
Million barrels per day	10.8	11.9	14.8	16.3
Trillion Btu	21,058	24,040	29,910	32,920
Supplemental supplies:[3]				
Million barrels	2,155.1	3,078	2,958	4,310
Million barrels per day	5.9	8.4	8.1	11.8
Trillion Btu	12,423	17,000	16,330	23,780
Percent of total supply	37.1	41.4	35.3	41.9

[1] Includes crude oil, condensate, and natural gas liquids.

[2] Details on synthetic liquids shown in that section of the report.

[3] May be from imports, shale oil, coal liquefication, etc. See text for explanation.

TABLE 4.—ESTIMATED GASEOUS FUEL SUPPLY SCHEDULE, 1974 PRELIMINARY AND PROJECTED TO THE YEAR 2000

	1974	1980	1985	2000
Total supply:				
Billion cubic feet	21,780	20,100	20,010	23,700
Trillion Btu	22,237	20,710	20,550	23,800
Domestic supply:				
Lower 48 natural gas:				
Billion cubic feet	20,840	18,880	16,750	13,610
Trillion Btu	21,277	19,470	17,260	14,040
Alaskan natural gas:				
Billion cubic feet			1,460	2,920
Trillion Btu			1,510	3,010
Synthetic gas:				
Billion cubic feet		120	500	4,670
Trillion Btu		110	450	4,200
Total domestic supply:				
Billion cubic feet	20,840	19,000	18,710	21,2 0
Trillion Btu	21,277	19,580	19,220	21,250
Gas imports:				
Pipeline imports:				
Billion cubic feet	940	800	700	1,000
Trillion Btu	960	820	720	1,020
Liquified natural gas:				
Billion cubic feet		300	600	1,500
Trillion Btu		310	610	1,530
Total imports:				
Billion cubic feet	940	1,100	1,300	2,500
Trillion Btu	960	1,130	1,330	2,550
Percent of total supply	4.3	5.4	6.4	10.7

TABLE 5.—CONSUMPTION OF UNITED STATES COAL RESOURCES BY MAJOR CONSUMING SECTORS, 1974 PRELIMINARY AND PROJECTED TO THE YEAR 2000 [1]

	1974	1980	1985	2000
Domestic consumption:				
Household and commercial:				
Million short tons	10.9	4	3	
Trillion Btu	292	100	100	
Percent of total [2]	2.0	0.5	0.4	0
Industrial:				
Million short tons	155	185	190	228
Trillion Btu	4,210	4,800	4,930	5,910
Percent of total [2]	28.5	25.2	21.1	15.7
Electrical generation:				
Million short tons	390.6	547	704	941
Trillion Btu	8,668	12,250	15,700	20,700
Percent of total [2]	58.7	64.3	67.3	55.1
Synthetic gas:				
Million short tons			26	300
Trillion Btu			520	6,000
Percent of total [2]	0	0	2.2	16.0
Synthetic liquids:				
Million short tons				91
Trillion Btu				2,140
Percent of total [2]	0	0	0	5.7
Total domestic demand:				
Million short tons	556.5	736	923	1,560
Million Btu	13,170	17,150	21,250	34,750
Percent of total [2]	89.2	90.0	91.0	92.5
Export demand: [3]				
Million short tons	59.1	70	75	100
Trillion Btu	1,584	1,900	2,100	2,800
Percent of total [2]	10.8	10.0	9.0	7.5
Total demand:				
Million short tons	615.6	806	998	1,660
Trillion Btu	14,774	19,050	23,350	37,550

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[1] Includes anthracite, bituminous, and lignite.
[2] Based on Btu content.
[3] Net exports.

W. J. LEVY CONSULTANT CORPORATION, "AN ASSESSMENT OF U.S. ENERGY POLICY." NEW YORK, SEPTEMBER 1976

ECONOMIC GROWTH

The study assumes that Government efforts will be directed toward reducing unemployment and increasing the utilization of the Nation's productive capacity. For analytical purposes, the study assumes that Gross National Product will grow at approximately 4 percent per year between 1975 and 1985, with substantial improvements over current unemployment rates.

ENERGY GROWTH RATES

On the basis of the above economic growth rates, the study projects energy growth rates of 3.5 percent per year. Every plus or minus 0.5 percent per annum in the energy growth rate will mean around 2½ million barrels per day of oil equivalent higher or lower by 1985. Total energy demand would rise from 34 million barrels per day in 1975 to 49 million barrels per day in 1985. Most rapid growth is expected in the electric utility sector, followed by the industrial sector.

OIL SUPPLY

The oil production projections are in the upper range of possible outcomes. The optimism is based on optimistic expectations of oil exploration and development programs. The study projects oil production to grow from about 10.5 million barrels per day in 1975 to 12.4 million barrels per day in 1985. To reach this level would require more than a 50-percent increase in annual additions to reserves over the 1958–75 additions to reserves. Oil imports are estimated at 10.6 million barrels per day by 1985 (see table A–1).

NATURAL GAS SUPPLY

Declines in natural gas production reflect the progressive reduction in natural gas reserves since 1973 (293 TCF at the end of 1967 to 216 TCF in December 1977). This study anticipates a favorable long-term response to the higher gas prices allowed in recent years by the Federal Power Commission. Further, moderate declines in production are projected for the period through 1985, and even these lower production figures assume a doubling in annual additions to reserves compared with the 1968–75 average annual reserve additions. It is assumed that an accelerated leasing program for offshore Government lands will be implemented. Imports of natural gas are assumed at a slightly higher level than in 1975 (see table A–2).

COAL

The study projects U.S. coal use to grow from 561 million tons in 1975 to 970 million tons in 1985. Exports would grow from 66 to 80 million tons in the same period.

Numerous demand and supply constraints are recognized, and the study assumes that several of these constraints will be removed.

About four-fifths of the increased coal use will be for the electric utilities industry. Some expansion is likely in the industrial sector (see table A–3).

NUCLEAR, HYDRO, AND GEOTHERMAL

Numerous environmental, institutional, and financial problems have lowered the nuclear power outlook significantly in recent years. Based on 1976 planning of the electric utilities, the study projects a maximum increase of nuclear power from 1.8 quads in 1975 to 8.7 quads in 1985.

Hydropower and geothermal steam are expected to add only modest additional volumes of electrical output through 1985. Virtually all of the increases from hydroelectric projects represent the addition of generating turbines at existing sites (see tables A–4 and A–5).

TABLE A–1.—U.S. SUPPLY AND DEMAND FOR PETROLEUM, 1973, 1974, 1975, AND PROJECTIONS FOR 1980 AND 1985

	1985	1980	1975	1974	1973
	Quadrillions of Btu's [1]				
Demand:					
Household/commercial	5.7	5.4	4.7	4.9	5.4
Industrial fuel	8.6	8.2	3.5	3.6	3.8
Industrial chemical	3.3	2.5	1.6	1.8	1.9
Industrial miscellaneous [2]	2.8	2.5	1.9	2.1	2.1
Transportation	21.5	19.8	17.7	17.5	18.0
Electric utilities	5.8	4.5	3.3	3.5	3.7
Total demand	47.7	42.9	32.7	33.4	34.9
	Thousands of barrels daily				
Demand:					
Household/commercial	2,830	2,650	2,300	2,417	2,674
Industrial fuel	3,990	3,770	1,596	1,666	1,773
Industrial chemical	2,100	1,580	1,007	1,127	1,149
Industrial miscellaneous [2]	1,260	1,140	904	932	928
Transportation	10,950	11,120	9,048	8,953	9,175
Electric utilities	2,560	1,980	1,436	1,534	1,609
Total demand	23,690	21,240	16,291	16,629	17,308
Supply:					
Domestic supply	13,000	12,000	10,508	10,941	11,418
Crude and condensate	10,800	9,900	8,362	8,765	9,187
Lower 48 [3]	8,800	8,300	8,362	8,765	9,187
North Slope	2,000	1,600	----	----	----
Natural gas liquids	1,600	1,600	1,670	1,724	1,768
Shale/coal liquefaction	100	----	----	----	----
Other supply [4]	500	500	476	452	463
Net imports	10,690	9,240	5,816	5,867	6,025
Less: Additions to storage	(5)	(5)	33	179	135
Total supply	23,690	21,240	16,291	16,629	17,308

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[1] Based on approximate Btu's per barrel for each petroleum product.

[2] Includes minor volumes used to manufacture synthetic gas.

[3] Includes Cook Inlet.

[4] Includes processing gain, crude losses, and unaccounted for crude.

[5] No allowance has been made for demand for stock bulidup in 1980 and 1985. Any inventory demand would also be reflected in higher net imports.

TABLE A-2.—U.S. SUPPLY AND DEMAND FOR NATURAL GAS, 1973, 1974, 1975, AND PROJECTIONS FOR 1980 AND 1985

	1985	1980	1975	1974	1973
	Billions of cubic feet daily				
Supply:					
Domestic marketed production	52.5	51.0	54.8	59.2	62.0
Conventional	51.0	51.0	54.8	59.2	62.0
New areas in Alaska	1.5				
Net imports	3.0	2.5	2.4	2.4	2.6
Canada	1.0	1.5	2.4	2.4	2.6
Liquified natural gas	2.0	1.0	(1)	(1)	(1)
Less: Extraction loss/additions to underground storage	3.5	3.5	3.1	2.7	3.8
Total supply	52.0	50.0	54.1	58.9	60.8
Demand:					
Household/commercial	25.8	24.4	20.5	20.1	20.5
Industrial fuel	13.8	10.7	16.5	20.8	21.9
Industrial chemical	2.9	2.1	1.9	1.9	1.9
Industrial miscellaneous	4.6	4.6	4.7	4.8	4.6
Transportation	1.6	1.6	1.7	1.9	2.0
Electric utilities	3.3	6.6	8.8	9.4	9.9
Total demand	52.0	50.0	54.1	58.9	60.8
	Quadrillions of Btu's				
Demand:					
Household/commercial	9.9	9.1	7.7	7.5	7.7
Industrial fuel	4.9	4.0	6.2	7.8	8.2
Industrial chemical	1.1	0.8	0.7	0.7	0.7
Industrial miscellaneous	1.7	1.7	1.8	1.8	1.8
Transportation	0.6	0.6	0.6	0.7	0.7
Electric utilities	1.2	2.4	3.3	3.5	3.7
Total demand	19.4	18.6	20.3	22.0	22.8

[1] Less than 0.05 billion cubic feet daily.

Note.—It is assumed that natural gas use by electric utilities will be severely restricted by governmental policies throughout the period. That restriction plus increased overall availability between 1980 and 1985 would permit increased industrial fuel usage over that period, reversing the 1973–80 trend. If electric utilities are permitted to burn more natural gas in 1985 than assumed, approximately the equivalent amount should be deducted from the industrial fuel sector.

TABLE A-3.—U.S. SUPPLY AND DEMAND FOR COAL, 1973, 1974, 1975, AND PROJECTIONS FOR 1980 AND 1985

	1985	1980	1975	1974	1973
	Millions of short tons				
Supply:					
Domestic production	1,050	890	643	610	599
Net exports	80	75	66	59	54
Stock addition (subtraction) [1]			16	(7)	(16)
Total supply	970	815	561	558	562
Demand:					
Household/commercial [2]	4	6	9	11	11
Industrial fuel	100	80	60	61	64
Industrial chemical	9	7	4	4	4
Industrial miscellaneous [3]	120	95	83	90	94
Electric utilities	737	627	405	392	388
Total demand	970	815	561	558	562
	Quadrillions of Btu's [4]				
Demand:					
Household/commercial [2]	.1	.1	.2	.3	.3
Industrial fuel	2.4	1.9	1.5	1.6	1.6
Industrial chemical	.2	.2	.1	.1	.1
Industrial miscellaneous [3]	3.0	2.5	2.3	2.4	2.5
Electric utilities	15.1	12.9	8.7	8.5	8.6
Total demand	20.8	17.6	12.8	12.9	13.1

[1] Includes losses and unaccounted for.

[2] Includes minor volumes used in transportation.

[3] Includes minor volumes used to manufacture synthetic gas in 1985.

[4] The average heat content of coal consumed by the industrial and electric utility sectors is projected decline by approximately 1,500,000 Btu's per ton between 1975 and 1985. Those reductions reflect the increasing proportion of surface mined western coal expected to be utilized by those sectors.

TABLE A-4.—U.S. GROSS INPUTS OF ENERGY FOR ELECTRICITY GENERATION, 1973, 1974, 1975, AND PROJECTIONS FOR 1980 AND 1985

	1985	1980	1975	1974	1973
	Trillions of Btu's				
Gross energy inputs	34,700	27,200	20,324	19,993	19,858
Petroleum	5,820	4,510	3,264	3,480	3,656
Natural gas	1,240	2,470	3,287	3,512	3,703
Coal	15,060	12,850	8,754	8,520	8,617
Hydro [1]	3,840	3,530	3,207	3,279	2,994
Nuclear	8,740	3,840	1,812	1,202	888
Net energy output [2]	11,260	8,800	6,534	6,407	6,394
Household/commercial [3]	6,660	5,200	3,954	3,742	3,747
Industrial	4,600	3,600	2,580	2,665	2,647
	Billions of kilowatt-hours				
Total available electricity	3,300	2,580	1,915	1,878	1,874
Petroleum	510	390	288	299	313
Natural gas	120	230	299	320	341
Coal	1,480	1,260	849	830	849
Hydro [1]	370	340	309	316	288
Nuclear	820	360	170	113	83
	Percentage distribution				
End-use sales [4]	100.0	100.0	100.0	100.0	100.0
Household/commercial [3]	59.1	59.1	60.5	58.4	58.6
Industrial	40.9	40.9	39.5	41.6	41.4

[1] Includes geothermal, other miscellaneous sources, and net imports.

[2] Conversion of electricity kilowatt-hours to Btu's using a rate of 3,412 Btu's per kilowatt-hour with distribution of sales to sectors based on proportion of sales to each sector.

[3] Includes minor volumes used in transportation.

[4] Based on electric utility sales reported by Edison Electric Institute.

TABLE A-5.—U.S. ENERGY CONSUMPTION/SUPPLY, 1975 AND 1985 PROJECTED

	Petroleum (million barrels daily)		Natural gas (billion cubic feet daily)		Coal (million short tons)		Nuclear (billion kilowatt hours)		Total consumption (million barrels daily oil equivalent)	
	1985	1975	1985	1975	1985	1975	1985	1975	1985	1975
Household/commercial	2.8	2.3	25.8	20.5	4	9			7.6	6.0
Transportation	10.9	9.1	1.6	1.7					11.2	9.4
Industrial	7.4	3.5	21.3	23.1	229	147			13.6	9.5
Electric utilities	2.6	1.4	3.3	8.8	737	405	820	170	16.3	9.3
Total supply	23.7	16.3	52.0	54.1	970	561	820	170	48.7	34.2
Domestic supply	13.0	10.5	49.0	51.7	970	561	820	170	37.5	28.0
Net imports	10.7	5.8	3.0	2.4					[1] 11.2	[1] 6.2

[1] Net petroleum and oil equivalent of natural gas imports only. Minor net electricity imports included in domestic supply. Does not consider net coal exports (largely metallurgical) of 800,000 and 1,000,000 bbl/d oil equivalent in 1975 and 1985 respectively. Also, no allowance is made for petroleum stock buildup.

Note.—Hydroelectric, geothermal, and net electricity imports included with total consumption, total supply, and domestic supply but not shown separately.

SHELL OIL COMPANY'S U.S. ENERGY OUTLOOK THROUGH 1990

This study was published in September 1976 and was made available in a digested form, providing a brief analysis of U.S. domestic supply and demand of energy. Shell uses its own energy resources estimates. Real GNP is projected to grow 4.5 percent per year between 1975 and 1980, and slow down to an average rate of 3.1 percent during the decade of the 1980's. By contrast energy growth rates are expected to grow at 2.2 percent per year from 1973 to 1980; 2.9 percent per year from 1980 to 1985, and 2.8 percent from 1985 to 1990. Hence Shell analysts assume that very substantial energy savings are possible during the rest of this decade, resulting in a much lower than traditional energy/GNP ratio. After the initial savings have worked their way through the economy, energy/GNP growth ratios are suggested to be very close again. This is interesting, in particular because many other analysts believe that it will be most difficult to lower the energy/GNP ratio during the next few tears but that chances for downward readjustments are better in later years.

Total energy demand is estimated to grow from an oil equivalent of 35.8 million b/d in 1973 to 41.6 million b/d in 1980; 48.1 million b/d in 1985; and 55.2 million b/d in 1990.

Oil demand grew at an average annual rate of 5.2 percent between 1965 and 1973. It is projected to decline to average annual growth rates of 3.1 percent between 1973 and 1980, and decline even further to 1.4 percent per year between 1980 and 1985 and 1.2 percent annually for the period from 1985 through 1990. Oil demand will slow down substantially in the transportation sector of the economy. Total oil demand will grow 16.4 million b/d in 1973 to 20.3 million b/d in 1980, 21.9 million b/d in 1985, and 23.3 million b/d by 1990.

Natural gas demand will decline through 1990 because of supply limitations. Most of the available gas will gradually be diverted from utility and industrial bollers to the residential-commercial sector, which will receive preferential allocation of limited natural gas supplies. Total natural gas demand will decline from about 22 TCF in 1973 to 20 TCF in 1980, 19 TCF in 1985, and 18 TCF in 1990.

Coal demand is not subject to supply controls during the period analyzed. Coal use is expected to grow from an annual average of about 1.3 percent between 1965 and 1973 to 2.1 percent per year between 1973 and 1980; 5.5 percent from 1980 to 1985; and 5.3 percent from 1985 to 1990. The biggest expansion is in the electric utility sector, followed by the undustrial sector.

Shell assumes a generally favorable political climate for the development of new energy sources; continued emphasis on environmental protection; higher oil and natural gas prices; development of Arctic gas and NPC No. 4 prior to 1985. Shell assumes oil decontrol after 1979 and higher prices for interstate natural gas.

OIL SUPPLY

Domestic oil production would increase from just over 10.5 million barrels per day in 1973 and 1980 to more than 11 million barrels per day in 1985 and a little more than 12 million barrels per day in 1990. Oil imports would increase from approximately 6 million barrels per day in 1973 to 10 million barrels per day in 1980, 11 million barrels per day in 1985, and 10 million barrels per day by 1990. Oil imports will increasingly have to come from the Middle East.

NATURAL GAS SUPPLY

Total domestic supply will decrease from about 21 TCF in 1973 to above 17 million barrels per day in 1980, 16 TCF in 1985, and 14 TCF by 1990. In order to meet projected demand, SNG from oil, syngas, and imports will have to fill the gap between demand and conventional gas supply.

COAL SUPPLY

Coal is primarily demand limited. Demand (including exports) is projected to increase from an oil equivalent of 6.9 million barrels per day in 1973, to 7.9 million barrels per day in 1980; 10.4 million barrels per day in 1985; and, 13.5 million barrels per day by 1990. Coal production could be substantially higher in each one of these years if there was sufficient demand.

NUCLEAR

The nuclear input into electricity generation is estimated to grow rapidly from an insignificant contribution in the early 1970's to about 4 quads in 1980; 10 quads in 1985; and, approximately 18 quads by 1990.

OTHER ENERGY SOURCES

Hydropower is projected to increase slightly between 1973 and 1990. Solar would begin to make a commercial contribution by 1985 and gradually add an oil equivalent of 1 million barrels per day to domestic energy supply.

Shell has not yet released a new U.S. energy forecast in 1978. A press release issued on February 10, 1978, gave some indication of Shell's most recent views on U.S. energy demand and supply through 1990.

In the news release, Shell shows a lower future rate of growth of U.S. energy demand compared with its 1976 analysis. The prime reason is a more pessimistic outlook for economic growth and to a lesser degree, the lower energy growth projections are said to be the result of increased prices and conservation.

The 1978 forecasts shows total energy demand to grow at 2 to 2.5 percent annually through 1990 (substantially below the 1976 Shell forecast). This is based on average annual GNP growth rates of 3.2 percent between 1980 and 1990. Hence, total energy demand is reduced to an oil equivalent of 40.3 million barrels per day in 1980 (41.6 million barrels per day in the 1976 study); 45.2 million barrels per day in 1985 (48.1 million barrels per day in the 1976 study); and, 50.6 million barrels per day in 1990 (55.2 million barrels per day in the 1976 study).

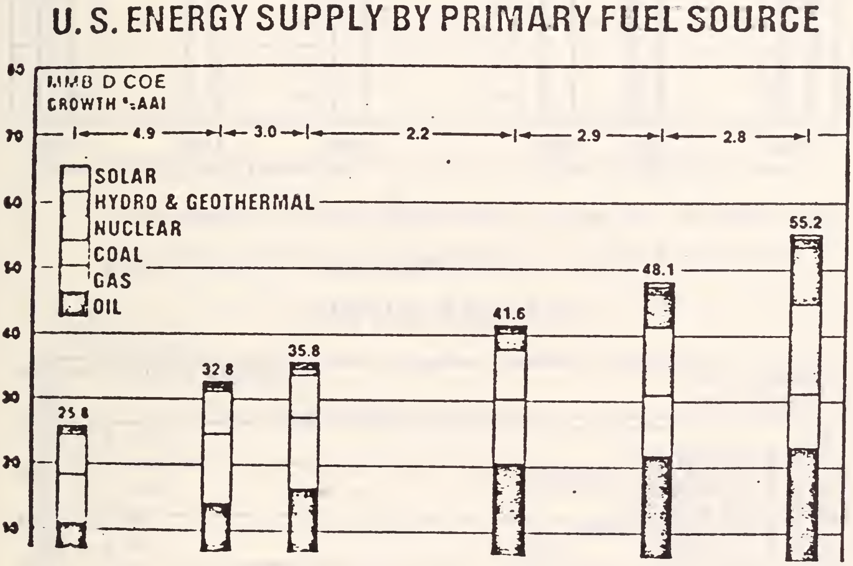
Domestic supply in the 1978 forecast has undergone several changes. Oil and natural gas production between now and 1990 is expected to be substantially lower than in the 1976 forecast. Coal use and the contribution of nuclear power to electricity generation have also been revised downward (see table 1).

TABLE 1.—U.S. ENERGY SUPPLY, 1980–90

[In million barrels per day oil equivalent]

	1980		1985		1990	
	Shell 1976	Shell 1978	Shell 1976	Shell 1978	Shell 1976	Shell 1978
Oil	10.4	9.5	10.9	9.4	12.1	10.1
Natural gas (conventional)	8.5	8.0	8.1	7.1	6.9	6.1
Coal (domestic use)	7.1	8.6	9.5	10.7	12.5	14.4
Nuclear	2.0	2.0	5.8	3.6	11.0	5.3
Other	1.4	1.4	1.4	1.4	1.5	1.5
Oil imports	10.0	10.0	10.7	11.3	10.2	11.3
Gas imports	1.2	0.9	1.1	1.6	1.1	1.8

FIGURE 1

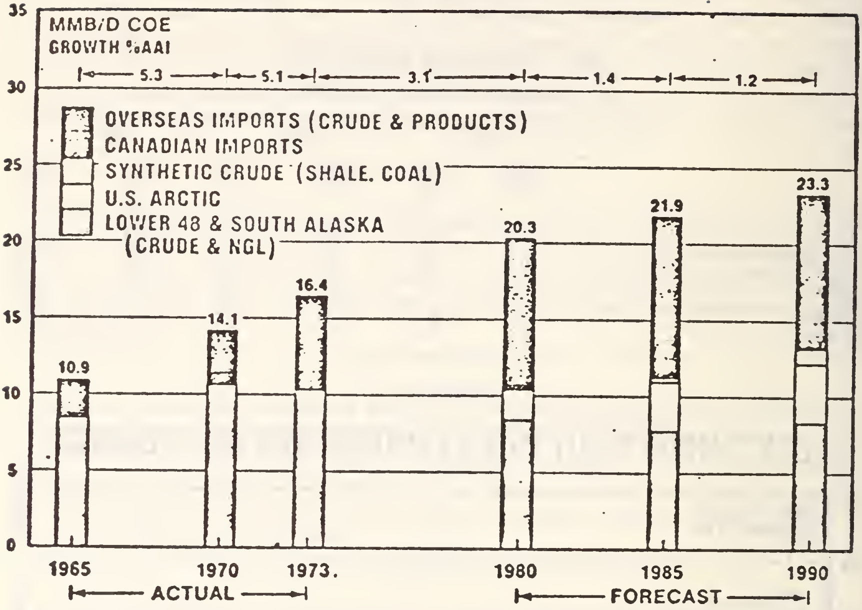


U. S. ENERGY SUPPLY BY PRIMARY FUEL SOURCE

Source: Shell Oil, "The National Energy Outlook 1980–90," September 1976.

FIGURE 2

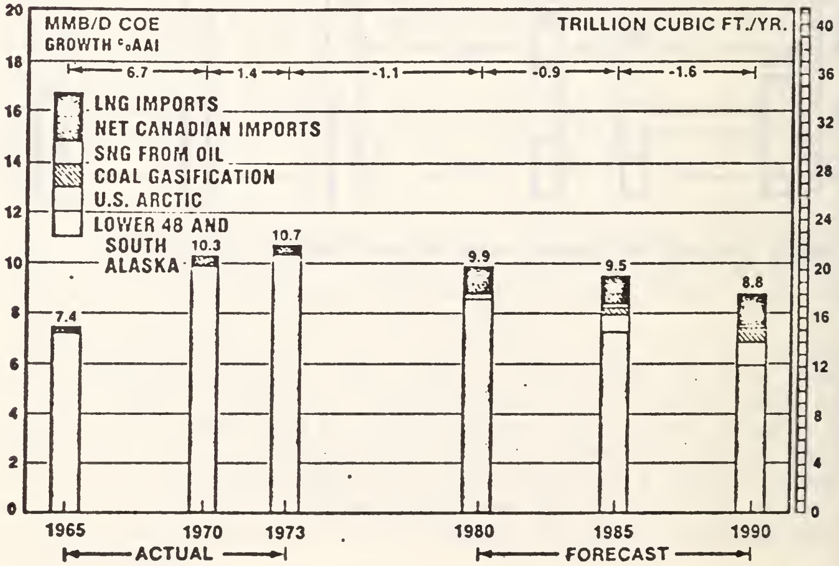
U.S. OIL SUPPLY



Source: Shell Oil, "The National Energy Outlook 1980–90," September 1976.

FIGURE 3

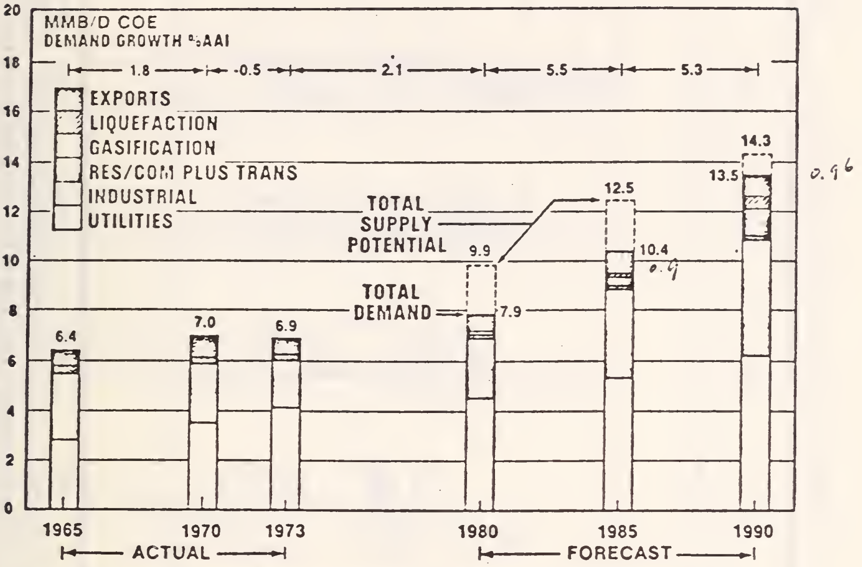
U.S. GAS SUPPLY



Source: Shell Oil, "The National Energy Outlook 1980–90," September 1976.

FIGURE 4

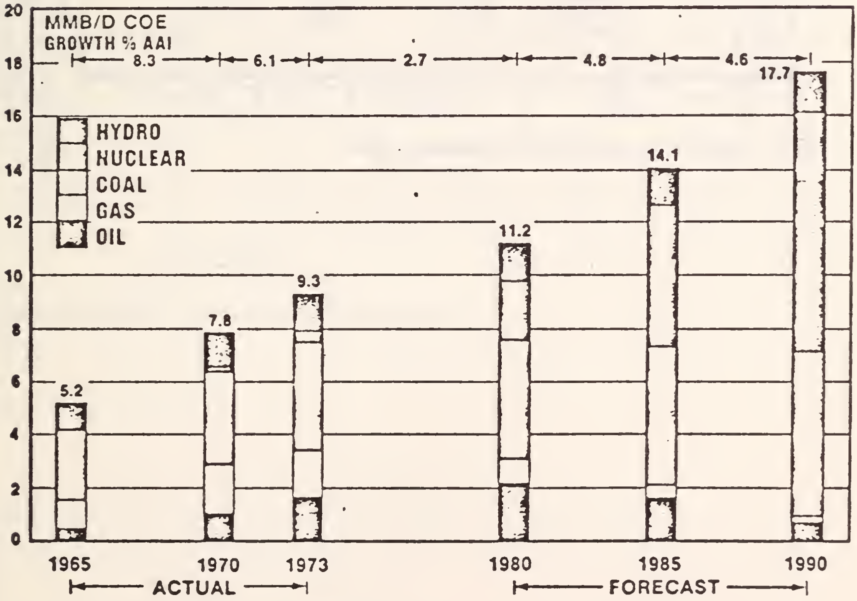
U.S. COAL DEMAND AND POTENTIAL SUPPLY



Source: Shell Oil, "The National Energy Outlook 1980–90," September 1976.

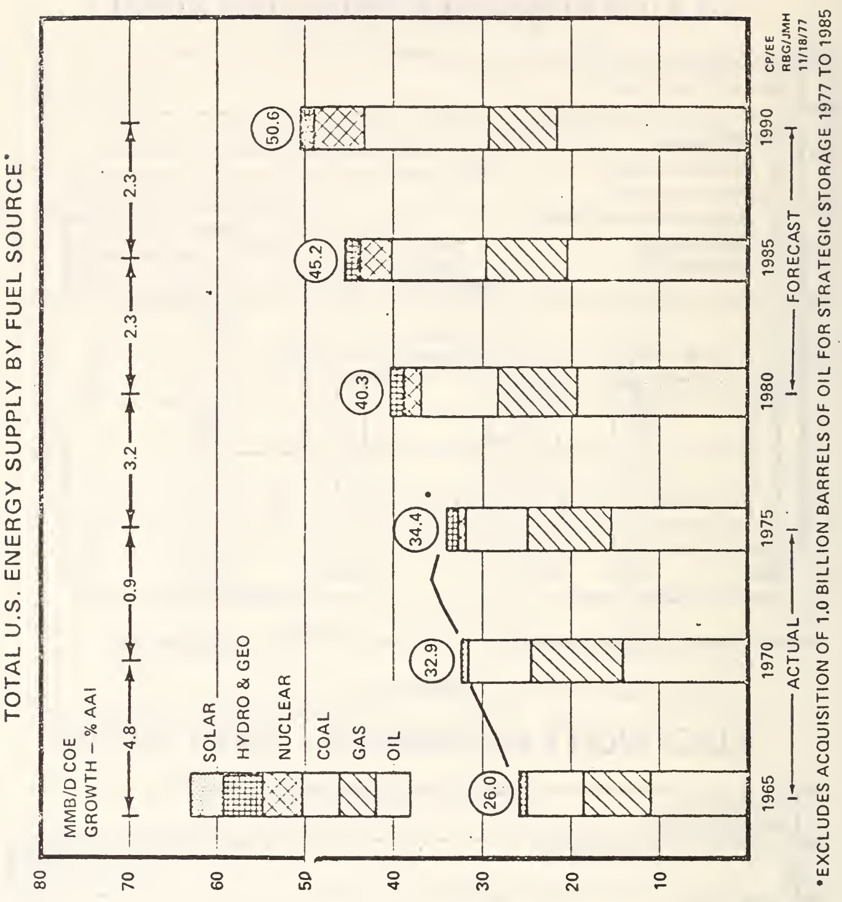
FIGURE 5

ELECTRICITY GENERATION - INPUT ENERGY



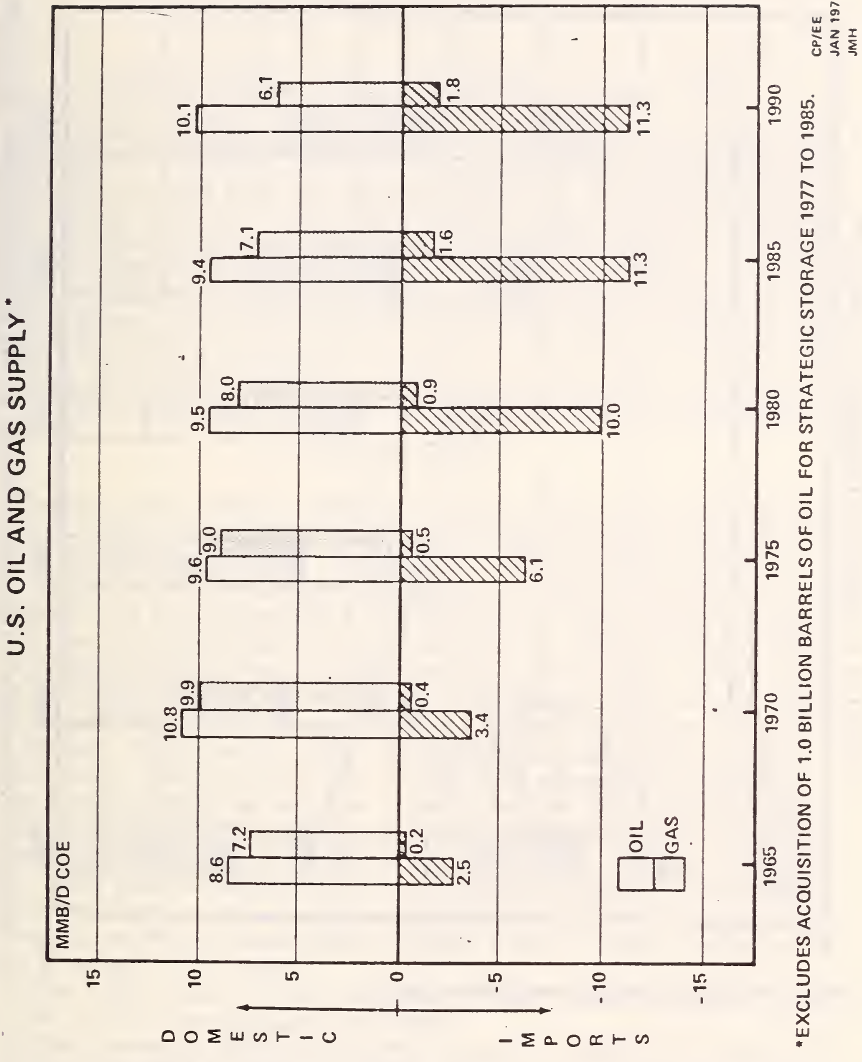
Source: Shell Oil, "The National Energy Outlook 1980–90," September 1976.

FIGURE 6.—Shell 1978 Projections



Source: Shell Oil Co., News Release, February 1978.

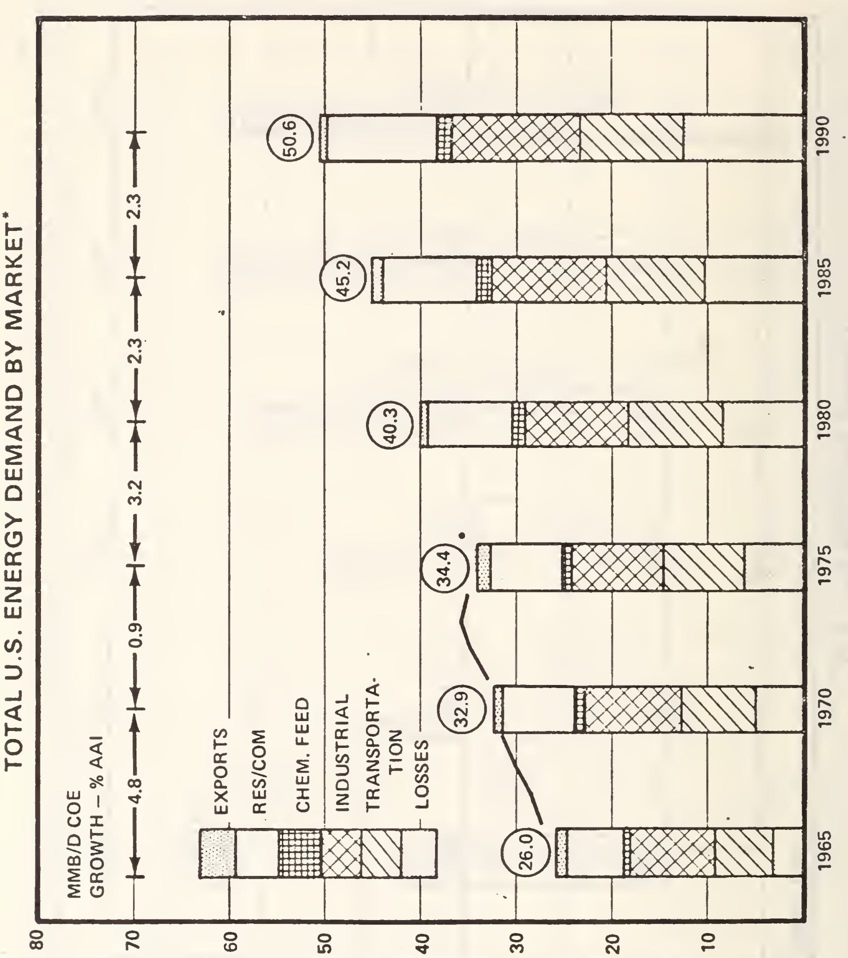
FIGURE 7.—Shell 1978 Projections



*EXCLUDES ACQUISITION OF 1.0 BILLION BARRELS OF OIL FOR STRATEGIC STORAGE 1977 TO 1985.

Source: Shell Oil Co., News Release, February 1978.

FIGURE 8.—Shell 1978 Projections



*EXCLUDES ACQUISITION OF 1.0 BILLION BARRELS OF OIL FOR STRATEGIC STORAGE 1977 TO 1985.

Source: Shell Oil Co., News Release, February 1978.

EXXON, ENERGY OUTLOOK, 1977–90, JANUARY 1977

This study provides a brief summary of domestic demand and supply of energy for the period 1976–90. The study assumes somewhat lower GNP growth rates than the official forecasts by Government agencies (3.5 percent per year) and energy growth rates of about 2.8 percent per year. The study further assumes: increased OCS leasing, a realistic balance between energy supply and environmental issues, no undue capital constraints; no forced savings, and gradually increasing energy prices. Exxon used its own resources estimates from a report entitled "U.S. Oil and Gas Potential."

Total U.S. energy demand is estimated to grow from an estimated 37.7 million bbl/d to 40.8 million bbl/d in 1980 and 54.3 million bbl/d by 1990.

OIL SUPPLY

Domestic oil supply is estimated to drop from about 10.0 million bbl/d in 1977 to 9.9 million bbl/d in 1980. Thereafter, production will rise to 10.6 million bbl/d in 1985 and 11.7 million bbl/d by 1990. Over half of the 1990 domestic production must come from reserves yet to be discovered (Alaska and the OCS). Shale oil is projected to supply 0.4 million bbl/d and synthetic oil from coal 0.1 million bbl/d by 1990.

Natural gas supply will decline to 15.6 trillion cubic feet in 1980, 15.4 trillion cubic feet in 1985, and 15.0 trillion cubic feet by 1990. Syngas production would grow from 0.4 trillion cubic feet in 1980 to 1.0 trillion cubic feet in 1990. Even at these declining production levels, half of the gas production of 1990 must come from new fields.

Coal use is expected to grow rapidly to some 754 million tons in 1980, 995 million tons in 1985, and 1,382 million tons in 1990. Exports of coal are estimated to rise from 60 million tons per year through 1980, to 85 million tons in 1985, and 90 million tons by 1990. In order to achieve those growth targets, western coal will have to increase at an annual rate of 11.7 percent (as opposed to 3.4 percent for eastern coal) to achieve the target.

Of the 1,382 million tons of coal use in 1990, about 82 million tons will be used to manufacture synthetics.

Nuclear power is estimated to grow from an estimated 51 gigawatts in 1977 to 74 GWe in 1980, 142 GWe in 1985, and 210 GWe by 1990. Nuclear power, which contributed about 11 percent of electrical power in 1977, would supply about one-third of domestic electrical power. There does not seem to be a potential uranium supply problem in the United States through 1990.

OTHER DOMESTIC SUPPLY

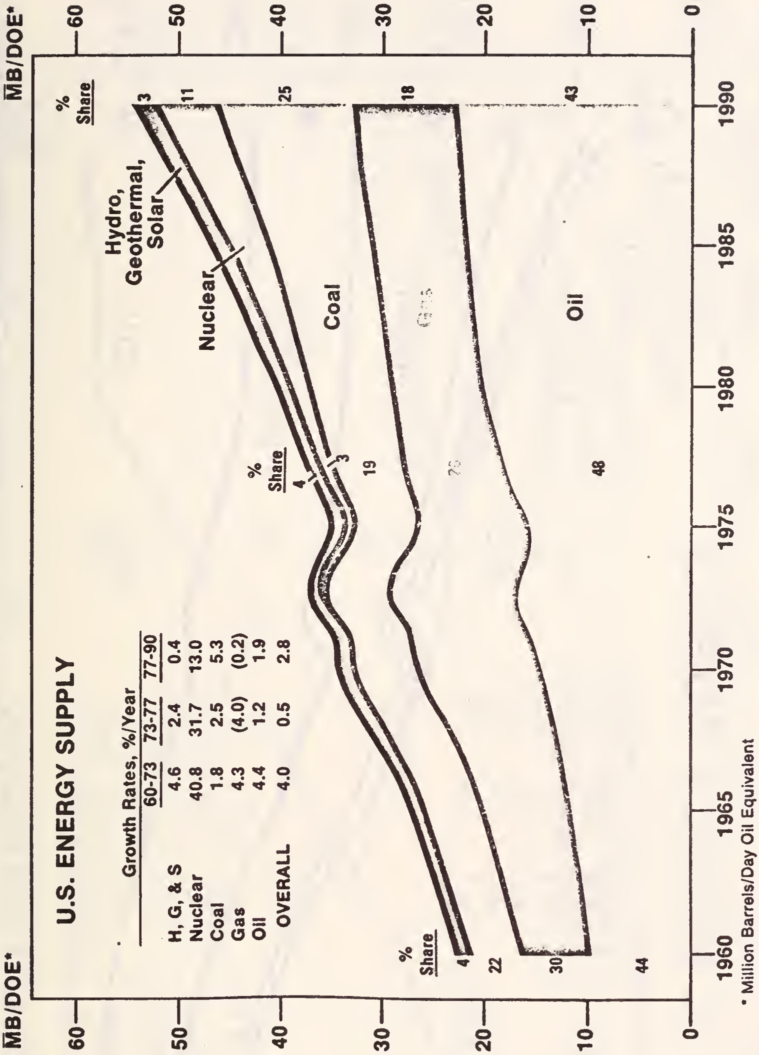
Hydropower will remain almost stable through 1990; geothermal power and solar energy will make make minor contributions to supply during the 1980's (see fig. 1).

EXXON, U.S. ENERGY OUTLOOK, 1978

Exxon has not published a 1978 update of its energy forecasts. However, available information on the 1978 forecast point in the direction of lower energy growth rates across the board; from an average annual growth rate of 2.8 percent estimated in the 1977 study to 2.4 percent in the 1978 study. The lower energy growth rates reflect more confidence in energy demand elasticity caused by a combination of higher prices and mandatory conservation measures (see figs. 2 to 9).

Domestic oil and natural gas supply which were already among the lowest oil company projections in 1977, have declined a little more in the 1978 forecast. Rapid coal demand in the utility sector will cause coal use to rise to over 10 million bbl/d oil equivalent in 1985 and 14 million bbl/d oil by 1980. Nuclear power's contribution to domestic energy supply is more disappointing than earlier forecasts, but it is still estimated to increase its share of U.S. energy supply from about 3 percent today to 10 percent by 1990.

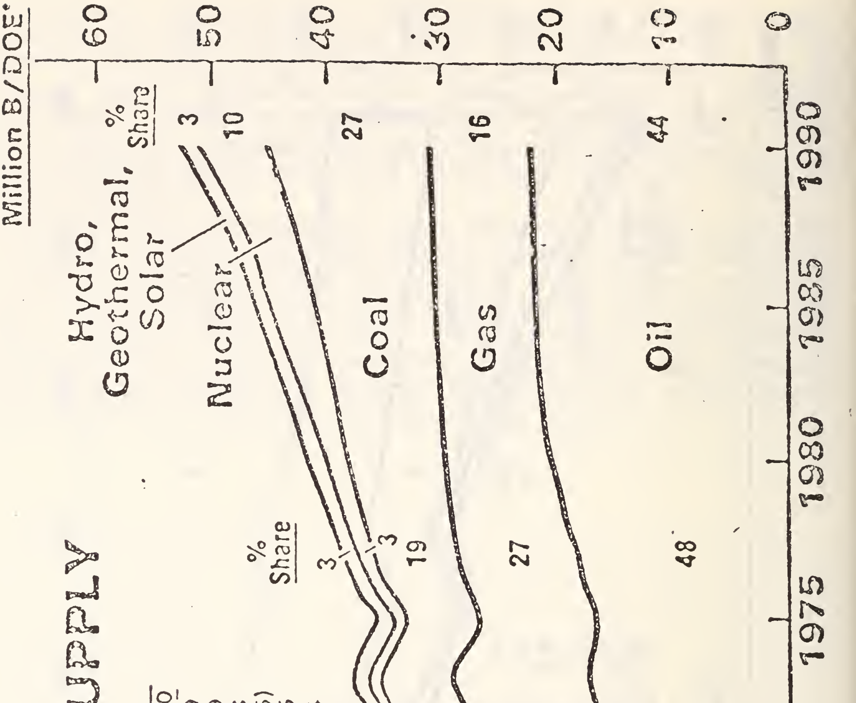
FIGURE 1



Growth Rates, %/Year	60-73	73-77	77-90
H, G, & S	4.6	2.4	0.4
Nuclear	40.8	31.7	13.0
Coal	1.8	2.5	5.3
Gas	4.3	(4.0)	(0.2)
Oil	4.4	1.2	1.9
OVERALL	4.0	0.5	2.8

* Million Barrels/Day Oil Equivalent

FIGURE 2

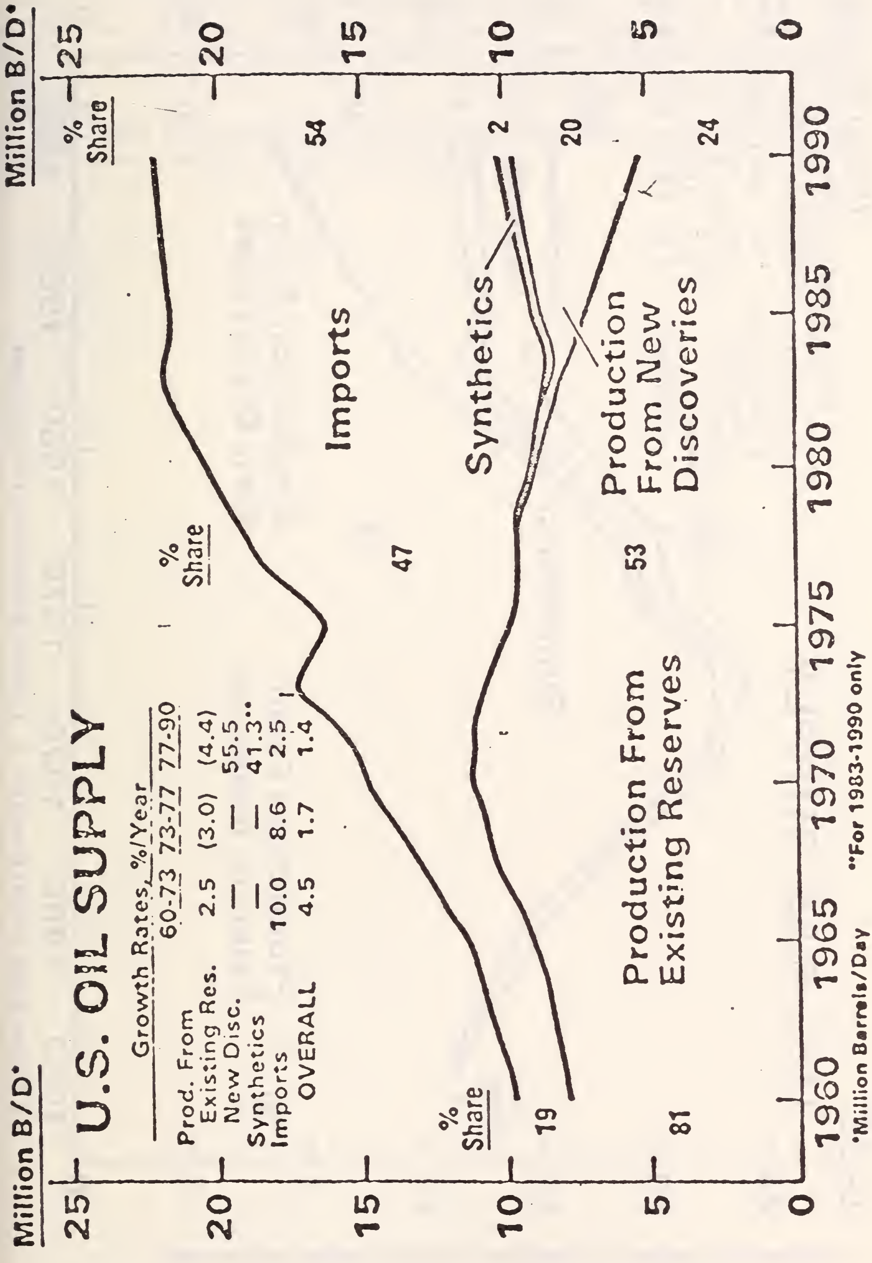


Growth Rates, %/Year

	60-73	73-77	77-90
H, G, & S	4.6	(2.2)	1.9
Nuclear	40.8	30.4	11.9
Coal	2.2	2.6	5.3
Gas	4.4	(3.2)	(1.5)
Oil	4.4	1.4	1.5
OVERALL	4.1	0.6	2.4

Data assume passage of President's energy program as proposed.

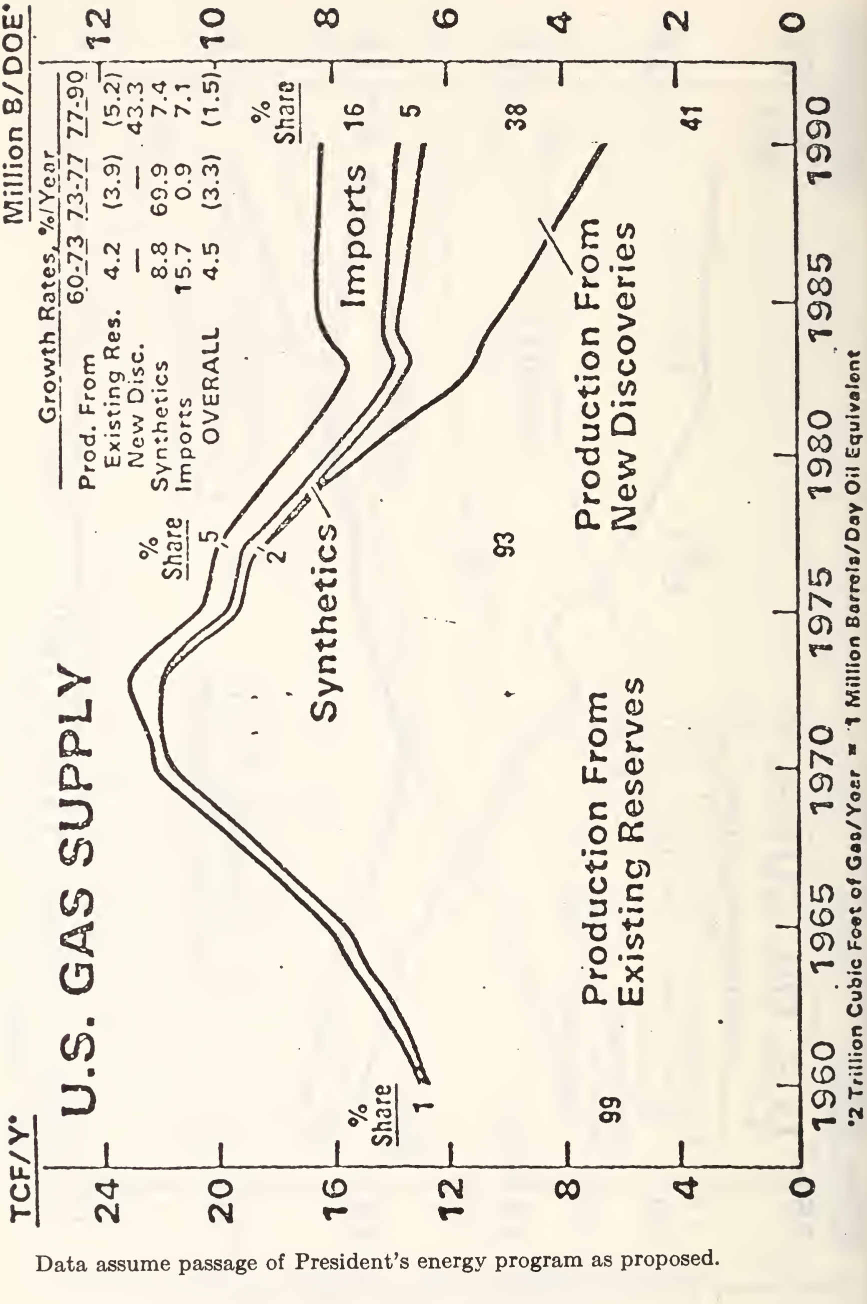
FIGURE 3



Growth Rates, %/Year	60-73	73-77	77-90
Prod. From Existing Res.	2.5	(3.0)	(4.4)
New Disc.	—	—	55.5
Synthetics	—	—	41.3**
Imports	10.0	8.6	2.5
OVERALL	4.5	1.7	1.4

Data assume passage of President's energy program as proposed.

FIGURE 4



Data assume passage of President's energy program as proposed.

One coal liquefaction plant producing 50,000 bbl/d of oil may be ready by 1990; two coal gasification plants may produce 0.5 trillion cubic feet of gas in 1985, and production of syngas may reach 1.5 trillion cubic feet by 1990 from six plants. Shale oil may supply 100,000 bbl/d in 1985 (two plants) and 400,000 bbl/d in 1990 (eight plants).

The 1978 Exxon demand/supply analysis assumes passage of President Carter's energy program as proposed.

Executive Office of the President, Energy Policy and Planning, the National Energy Plan, Washington, D.C., April 29, 1977

REASON FOR THE CRISIS

In the first chapter of the White House report, the origins of the U.S. energy problem are analyzed. It is said to have come about partly through the lack of foresight. Americans have been accustomed to abundant, cheap energy. During the decades of the 1950's and 1960's, the real price of energy in the United States fell 28 percent. And from 1950 until the quadrupling of world oil prices in 1973–74, U.S. consumption of energy increased at an average annual rate of 3.5 percent. As a result of the availability of cheap energy, the United States developed a stock of capital goods—such as homes, cars, and factory equipment—that uses energy inefficiently.

The most critical increase in demand has been for oil and natural gas, which now provide for about two-thirds of U.S. energy consumption. Oil production peaked in 1970. Natural gas, at first a wasted byproduct of oil discoveries, was later utilized, when it could be transported through pipelines to markets. It, too, expanded rapidly, and production peaked in 1973–74. Domestic coal production did not expand, and although nuclear power grew rapidly, the total gap between energy demand and supply continued to grow throughout the 1970's. The gap was filled increasingly with imported oil, which grew from 0.9 million bbl/d in 1950 (when the United States had still a production surplus, but oil was imported because it was cheaper) to 3.4 million bbl/d in 1970 and 7.2 million bbl/d in 1976. In 1977, total oil imports surpassed 8.5 million bbl/d.

Prior to the Arab oil embargo there was no good reason in the United States to emphasize energy conservation. Domestic sources of energy and imported oil were considered adequate for decades to come, and nuclear power—too cheap to meter—would gradually replace oil and gas as the major energy sources. Hence, when real prices of energy continued to fall, demand for energy closely followed GNP growth rates—3.6-percent average annual GNP growth rate and 3.5-percent annual energy growth rate. Little efforts were put into home insulation, construction of energy-efficient cars, improvement of mass transportation, and so on. General improvement in the standard of living led to purchases of more air-conditioners, larger homes, more appliances, and cars equiped with energy-consuming extras during the two decades preceeding the Arab oil embargo.

Government policy generally stimulated energy demand by granting tax benefits to producers and keeping prices down for consumers. This kept the price of energy below its true replacement cost, thereby promoting consumption and waste. Large consumers of natural gas and electricity have been given discounts; interests air and truck transporation has been subsidized and energy-inefficiency protected. Major highway construction and the subsequent move into the suburbs have made people believe that energy will always be cheap.

On the energy supply side, oil and natural gas production have peaked, and although production is projected to increase for oil in the national energy plan, the end of the oil and gas era is in sight. America is on the verge of another major transition period; away from liquid fossil fuels to a variety of alternative energy systems.

Three stages are foreseen in this transition period: (1) 1977–85: reduction of the rate of growth for demand and oil in particular, reallocation of natural gas to high priority uses, increase production from abundant energy sources, and construct a strategic petroleum reserve; (2) Result: by the mid-1980's, when the authors of the report expect world oil production to peak, the United States could be in a position to reduce its demand for foreign oil; (3) Beyond 2000, new energy sources are needed to replace dwindling oil and gas resources.

The White House warns that if America acts now, it can accomplish the transition in an orderly way; with sufficient time, the United States can modify its capital stock to make it more efficient. However, if action is delayed, the transition will have to be made abruptly with measures, such as rationing, that operate directly on behavior and at the expense of the immediate flow of goods and services.

ANOTHER QUADRUPLING OF THE PRICE OF OIL?

The White House does not expect another oil price hike like the one in 1973. However, if demand for world oil is not drastically reduced, the White House foresees that world oil demand will outpace supply by the middle 1980's. Hence, continuing reliance on growing oil imports will not—in the long run—satisfy American energy demand. The principal oil-exporting countries will not be able to satisfy all the increases in demand expected to occur in the United States and other countries throughout the 1980's.

The White House report states that OPEC exports in 1976 amounted to 29 million barrels per day. If world demand continues to grow at the rate of recent years, by 1985, demand for OPEC exports could reach or exceed 50 million barrels per day. However, many OPEC countries cannot significantly expand production; and, in some, production will actually decline. Thus, as a practical matter, overall OPEC production could approach the expected level of world demand only if Saudi Arabia greatly increased its oil production. Even if Saudi Arabia did so, production would probably be inadequate to meet increased world demand beyond the late 1980's or early 1990's. Beyond limitations imposed by producer states for economic or other reasons, the report agrees with other recent studies that there are physical constraints to continued reliance on imported oil. World oil resources are said to be around 2 trillion barrels of which 360 billion already have been consumed. Another 600 billion barrels are proved, leaving another 1,400 billion to be discovered. At a rate of growth of 3 percent—one-half of historical oil production growth rate—these reserves and undiscovered recoverable oil resources would be exhausted before 2020—at 5 percent growth by 2010. Long before exhaustion, oil production would of course have peaked, requiring dwindling production of oil to be replaced by other fuels.

Despite some uncertainty about the exact size of recoverable world oil resources, and about the rate of increase of productive capacity, this fundamental fact is clear: within about four generations, the bulk of the world's supply of oil, created over hundreds of years, will have been substantially consumed.

The report recognized that physical exhaustion of oil will not actually occur; there will continue to be tertiary recovery methods to lift more oil from existing fields, and eventually there will be substitutes for shale, coal, or tar sands. But, these will be very expensive, and some will have to be reserved for petrochemicals and other uses in which it has maximum value.

It is clear to the authors of the national energy plan, that current consumption of 20 billion barrels per year cannot continue indefinitely. We would have to add another Kuwait or Iran every 3 years or another Texas or Alaska every 6 months. The report suggests that such finds are highly unlikely. Indeed, it is stated, recent experience suggests that, compared to world oil consumption, future discoveries will be small or moderate in size, will occur in frontier areas, and will yield oil only at very high cost. Obviously, it is said, high rates of growth of oil consumption simply cannot be sustained.

In order to reduce U.S. dependence on foreign oil, the administration presented Congress with the national energy plan in April of last year. The following principles led to the formulation of the plan:

(*a*) Energy problems can be effectively addressed only by a government that accepts responsibility for dealing with it comprehensively, and by a public that understands its seriousness and is ready to make necessary sacrifices.

(*b*) Healthy economic growth must continue—conservation creates jobs.

(*c*) A national policy for the protection of the environment must be maintained. (In the long run there is no unsurmountable conflict between the twin objectives of meeting energy needs and protecting the high quality of the environment—improving energy efficiency and harnessing waste will solve many energy and environmental problems.)

(*d*) The United States must reduce potentially devastating oil supply interruptions—continued growth in oil imports erodes the Nation's economic security, promotes dissemination with allies, and jeopardizes America's world leadership. No crash program to achieve energy independence are needed. There is no justification for massive, reckless development of all U.S. energy resources, depletion of critical domestic oil and gas reserves, pollution of the environment, draconian conservation measures, and rejection of the substantial economic benefits of oil imports, all in the name of energy independence.

(*e*) Energy problems in the United States must be solved in a manner that is equitable to all regions, sectors, and income groups. (Avoid energy Balkanization.)

(*f*) Energy growth must be restrained through conservation and improved energy efficiency—cheap and effective way to protect the environment—some sacrifices of comforts.

(*g*) Energy prices should generally reflect the true replacement cost of energy. (Expensive foreign oil mixed with cheap domestic oil leads to waste.) Windfall profits—explained as receiving tomorrow's prices for yesterday's discoveries—must be avoided.

(*h*) Energy producers and consumers are entitled to reasonable certainty as to Government policy—clear and consistent policy needed.

(*i*) Resources in plentiful supply must be used more widely, and the Nation must begin the process of moderating its use of those in short supply.

(*j*) The nonconventional sources of energy must be vigorously expanded.

THE UNITED STATES HAS THREE OVERRIDING ENERGY OBJECTIVES

(1) Reduce dependence on foreign oil to limit vulnerability to supply interruptions.

(2) In the medium term, weather the stringency in world oil supply that will be caused by limitations in productive capacity.

(3) Long-term development of renewable sources of energy for sustained economic growth.

NATIONAL ENERGY PLAN

To achieve the above objectives, the plan contains three major components.

(1) By carrying out an effective conservation program in all sectors of energy use, through reform of utility rate structures, and by making energy prices reflect true replacement cost, the Nation should reduce the annual rate of growth of demand to less than 2 percent. (Serves both Nos. 1 and 2 of the listed energy objectives.)

(2) Utilities and industries using oil and natural gas should convert to coal and other abundant fuels. Will reduce imports and make more gas available for households. Conversion meets both immediate and medium-term objectives.

(3) A vigorous research and development program to provide renewable and other resources to meet the energy next century.

Other components: (a) A strategic petroleum reserve to meet potential supply interruptions; (b) Encourage oil and gas production in frontier areas and advanced recovery techniques; (c) Develop alternative sources of gas. Coal conversion is one of those promising methods.

ALTERNATIVES

(A) Through piecemeal programs and policies, continue the current state of drift. No hard decisions, no major sacrifices. Attractive in the short run, but with each passing day, the Nation falls further behind in solving its energy problems.

(B) National energy plan.

EFFECTS OF THE NATIONAL ENERGY PLAN ON ENERGY DEMAND AND SUPPLY

In order to slow down energy use, the administration proposed a number of tax measures, which are to have the effect of reducing the energy/GNP ration from more than 0.9 for each unit of GDP produced to about 0.5 for each unit of GNP produced.

The national energy plan foresees annual economic growth rates between now and 1985 to average at slightly more than 4 percent. Energy growth rates are projected to be just below 2 percent per year by 1985 as a result of conservation efforts. With the plan energy consumption by 1985 is projected to be 46.4 million barrels per day oil equivalent; without the plan, consumption would have been 48.3 million barrels per day oil equivalent. Total savings from conservation: 1.7 million barrels per day (see table 1). Conservation is to be achieved by taxes on cars gasoline in the transportation sector, coupled with a number of direct measures to reduce consumption in this sector of the economy. The plan proposes tax credits for home insulation and installation of solar equipment, and mandatory building standards to accelerate efficiency. The plan promotes cogeneration of steam and electricity, and calls for utility reform.

On the supply side, a number of measures are proposed to encourage coal conversion and conservation of oil and natural gas. There is some encouragement for exploration and development of new oil fields, stripper wells and tertiary recovery from old fields. All domestic oil would be subject to a wellhead tax which will bring the price of oil in three stages up to the world market price. The revenue of the tax is to be returned to the economy.

The distinction between inter- and intrastate natural gas will disappear; instead, all new natural gas will be subject to a maximum price limitation of $1.75 per thousand cubic feet. Other gas would qualify for a price no higher than the current $1.42 per Mcf ceiling. New and more expensive gas is to be allocated to industrial users. Taxes will be levied on industrial and utility users of oil and natural gas and to encourage conservation and conversion to coal or other energy sources. Specific high cost gas such as gas from geopressurized zones will not be subject to the price ceiling.

Other additional provision on oil and gas include encouragement to develop Alaskan oil from existing wells by allowing the upper tier wellhead price of $11.28 per barrel; new Alaskan oil would be subject to the new oil wellhead tax; the Outer Continental Shelf Lands Act will be amended to include a variety of bidding systems and to insure a fair return to the public; shale oil will be entitled to the world oil price; additional Federal programs for development of geopressurized gas and gas from Devonian shale; LNG policy will be reviewed, gasoline decontrolled, and a new study made concerning a national energy transportation plan. Finally, the strategic petroleum reserve will be expanded to 1 billion barrels.

COAL

New utility and industrial boilers will be prohibited from burning oil and natural gas, except under extraordinary circumstance, and by 1990 virtually no utilities will be permitted to burn natural gas. Existing facilities with coal-burning or gas.

To prevent deterioration of the environment, best available control technology will be required for all coal-fired plants, including those that burn low-sulfur coal. Further tightening of Clear Air Act provisions. Additional research and development programs to develop the most effective ways to use coal in its actual form or in the form of coal gas or synthetic oil.

NUCLEAR POWER

Plutonium recycling and the breeder reactor program are being postponed. To encourage others to follow U.S. policy, new orders for U.S. uranium enrichment services will be accepted only under specific conditions, and expansion of U.S. enrichment facilities is called for.

Legislation is called for to guarantee enrichment of uranium to any country that shares U.S. nonproliferation objective and accepts conditions consistent with those objectives.

Additional protection of light-water nuclear reactors is called for to prevent mishaps caused by man or machine. Expansion of waste disposal storage facilities is called for, and a new study will be made of the nuclear licensing process.

ALTERNATIVE ENERGY SOURCES

The Corps of Engineers will report on the potential of additional hydroelectric generating capacity at existing dams in the country; the tax deduction for intangible drilling costs now available for oil and gas would be extended to geothermal drilling; special tax credits are offered for installation of solar hot water and space heating systems; an effective R. & D. program is called for to support many research options in the early stages, but only for continued support into the later stage for programs meeting technical, economic, national security, health, safety and environmental criteria.

The following tables show the results expected by the administration from the proposed national energy plan.

TABLE 1.—FUEL BALANCES BY SECTOR

[Millions of barrels of oil equivalent per day]

	1976	1985 without plan	1985 with plan	1985 plan plus additional conservation
Supply	37.0	48.5	46.4	45.2
Domestic:				
Crude oil [1]	9.7	10.4	10.6	
Natural gas	9.5	8.2	8.8	
Coal	7.9	12.2	14.5	
Nuclear	1.0	3.7	3.8	
Other	1.5	1.7	1.7	
Refinery gain	.4	.9	.6	
Total [2]	30.0	37.1	40.0	
Imports/exports (—):				
Oil	7.3	11.5	7.0	5.8
Natural gas	.5	1.2	.6	
Coal	—.8	—1.2	—1.2	
Total [3]	7.0	11.5	6.4	5.2

[1] Includes natural gas liquids.

[2] Detail may not add due to rounding.

TABLE 2.—BALANCES BY FUEL[1]

[Millions of barrels of oil equivalent per day]

	1976	1985 without plan	1985 with plan	1985 plan plus additional conservation
Oil:				
Consumption	17.4	[2] 22.8	18.2	17.0
Domestic supply[3]	9.7	10.4	10.6	10.6
Refinery gain	.4	.9	.6	.6
Imports	7.3	11.5	7.0	5.8
Natural gas:				
Consumption	10.0	9.4	9.4	
Domestic supply	9.5	8.2	8.8	
Imports	.5	1.2	.6	
Coal:				
Consumption	6.8	10.9	13.3	
Domestic supply	7.9	12.2	14.5	
Exports	.8	1.2	1.2	

[1] Detail may not add up to total due to rounding.

[2] Assuming compliance with automobile efficiency standards under current law, and reduced driving as a result of higher gasoline prices. Without these assumptions, consumption would be 25 million barrels per day.

[3] Includes natural gas liquids.

TABLE 3.—FUEL BALANCES BY SECTOR

[Millions of barrels of oil equivalent per day]

	1976	1985 without plan	1985 with plan	1985 plan plus additional conservation
Demand	37.0	48.3	46.4	45.2
Residential and commercial:				
Oil	3.5	3.2	2.7	
Natural gas	3.9	3.8	4.1	
Electricity	6.3	9.1	8.4	
Coal	.1			
Total	13.8	16.1	15.2	
Industry:				
Oil	3.2	7.0	4.0	
Natural gas	4.4	4.5	4.5	
Electricity	4.2	7.2	7.1	
Coal	1.9	2.7	5.0	
Total	13.7	21.4	20.6	
Transportation:				
Oil	9.2	10.6	10.2	
Natural gas	.3	.2	.3	
Total	9.5	10.8	10.5	
Electricity:				
Oil	1.6	2.0	1.3	
Natural gas	1.5	.9	.5	
Coal	4.9	8.2	8.3	
Nuclear	1.0	3.6	3.8	
Other	1.5	1.6	1.6	
Total	10.5	16.3	15.5	

GENERAL ACCOUNTING OFFICE, AN EVALUATION OF THE NATIONAL ENERGY PLAN, WASHINGTON, D.C., JULY 1977

OVERALL OBSERVATIONS

The administration has taken a very important first step in developing a national energy policy. It is a first start. GAO is in agreement with the general thrust of the program and most of the specific initiatives proposed. Unfortunately the plan is not strong enough to meet many of its objectives, including a major reduction in oil imports.

The administration's goals and its estimate of what the plan can accomplish are as follows:

ADMINISTRATION'S PROPOSED ENERGY GOALS FOR 1985	ADMINISTRATION'S ESTIMATE OF WHAT THE PLAN CAN ACCOMPLISH THROUGH 1985
1. Reduce total energy growth to below 2 percent/year.	Reduction to 2.2 percent (note a).
2. Reduce oil imports below 6 million barrels/day.	Reduction to 7 million barrels/day (note a).
3. Reduce gasoline consumption by 10 percent from 1977 levels.	Reduction of 10 percent from 1977 levels.
4. Increase coal production by at least 400 million tons over 1976.	Increase by 565 million tons.
5. Insulate 90 percent of all buildings.	Insulate approximately 60 percent (note a).
6. Use solar energy in 2.5 million homes.	Use solar energy in 1.3 million homes (note a).
7. Acquire Strategic Oil Reserve of 1 billion barrels of oil.	Acquire 1 billion barrels of oil.

The GAO report agrees with the goals, but believes that the national energy plan is not expected to achieve them. GAO maintains that on the basis of the administration's estimates, the conservation provisions of the plan will not cause much reduction in demand. No action would result in 31-percent increase in demand between 1976 and 1985; with the plan it would still grow by 25 percent with the plan fully implemented. This equates to a reduction of about 1.9 million bbl/d, or only 4 percent of total demand after 9 years.

The major impact of the plan, as proposed, seems to be reducing oil imports by shifting to coal rather than by conserving energy.

ENERGY SUPPLY/DEMAND BALANCES

The supply side of the equation makes GAO conclude that unless energy demand is reduced, the level of imported oil is likely to be about 4.3 million bbl/d more than the administration's goal of 6 million bbl/d.

	Mmb/d oil equivalent
Administration's goal for oil imports in 1985	6. 0
Administration's estimate of reduction due to voluntary actions	+1. 0
Our estimate of additional imports required to compensate for lower amounts of domestic production for:	
Coal	+2. 3
Natural gas	+1. 0
Nuclear power	+. 6
Our estimate of reduced oil imports as a result of higher imports of liquefied natural gas	−. 6
Total 1985 oil imports	10. 3

This estimate assumes the full savings of 1.9 million bbl/d oil equivalent, but does not include savings as a result of voluntary public response from which the administration hopes to save 1 million bbl/d oil equivalent.

Oil imports will have to compensate for the shortfall in domestic production—unless further conservation is achieved.

The choice is between more imports or more conservation. Stronger mandatory conservation measures are needed in the event the Nation falls short of the goals. It would help if it were known what those mandatory actions would be.

DEMAND

The administration's forecast for energy consumption is based on annual GNP growth rate of 4.3 percent through 1985 which is comparable to the growth rates of the 1960's.

Energy consumption in the industrial sector is higher than ever experienced in any 9-year period since World War II. In 1960–73 when GNP rose at annual rates of 4 percent energy consumption in industry grew at 3 percent per year. This is also the upper limit in GAO's projection through 1985. On the other hand, GAO believes that the administration's projections for residential/commercial growth rates—estimates at 0 percent with the plan, 0.6 percent without it—appears questionable (1960–73 average growth rate in this sector was 1.5 percent. In the transportation sector the administration projects growth rates to decline from an average of 4.3 percent in 1960–73 to 1.4 percent through 1985 without the plan and 1.1 percent with the plan. This is difficult to achieve according to GAO because trucks and vans are not likely to achieve the significant savings projected for passenger cars.

GAO believes that the public is not enough concerned with the need to conserve energy, because in the public view there have been—until this winter (1976–1977)—adequate energy supplies;

That there is a general lack of financial incentives and/or disincentives to encourage and influence adoption and application of conservation actions; and

Not enough energy is being conserved. Although substantial potential exists in the industrial, transportation, commercial, and residential sectors.

SUPPLY: OIL

The GAO study points out that there is little difference between the administration's oil production supply figures with the plan and with out the plan. Existing policy would lead to a production level of 9.2

million bbl/d of crude oil and 1.2 million bbl/d of NGL. The plan provides for a production of 9.2 million bbl/d of crude oil and 1.3 million bbl/d on NGL. Hence, the plan will produce only 0.1 million bbl/d of NGL more than what existing policy would lead to.

GAO calculated that by 1985 old oil prices under the plan will be about $1.15 lower than under existing policy, and new oil will be $2.22 lower 1985 than under existing policy.

GAO concludes that it is not in a position to gage the precise response of production in the old, new, and already discovered Alaskan oil categories to lower prices, but it seems reasonable that there may be some effect. If so, the plan could result in less production than under a continuation of existing policy.

The GAO also concludes that the plan will reduce revenues to producers for most oil already discovered and may adversely affect oil companies' financial ability to support additional exploration. By not increasing the financial incentives for additional exploration and by reducing companies' financial strength, the plan fails to come to grips with the problem of increasing domestic crude oil production.

The GAO recognized the administration's reluctance to confer windfall profits on the oil industry by increasing their revenues for already discovered and developed oil, but argues that means should be sought to increase domestic supply. Although GAO has not yet studied alternative pricing systems, it urges the careful evaluation of alternative pricing schemes to achieve the objectives. One could, for example, tie the price of domestic oil to the world market price rather than tying the price of newly discovered oil to the U.S. inflation rate. GAO does not suggest complete decontrol of oil, and it favors the concept of the oil equalization tax. The GAO also suggests that the Government develop an overall exploration plan for the Outer Continental Shelf and finance stratigraphic test drilling for oil and natural gas in areas where information is needed to complete the plan and private industry does not plan to drill.

NATURAL GAS

The GAO agrees with the administration on the implications of deregulation. It concluded that higher prices for natural gas, even under total deregulation, would result in increased gas supplies over current levels at least through 1985. GAO does not believe that the amount of new reserves will be found to raise production levels. For example, without any new discoveries of gas, production will be down to 8 trillion cubic feet by 1985.

To bring production up to 15 TCF, some 12 TCF a year of additional reserves will have to be found between 1976 and 1985 (last year about 7 TCF was added). Because of the experience in natural gas reserve additions since 1969, half of the 12 TCF average annual reserve addition would have to come from new discoveries. Over any extended period since 1945, new field discoveries have never exceeded 6 TCF per year. Therefore, GAO concludes that annual reserve additions of 12 TCF a year would be a maximum amount one could reasonably count on attaining over the next 10 years. This does not include gas from nonconventional sources such as Devonian shale. GAO does not expect significant production from any of these nonconventional sources by 1985.

The administration's estimated production for 1985 would require reserve additions of 16 TCF without the plan and 20 TCF per year with the plan. GAO considers this unreasonable. Hence, GAO concludes that the administration's natural gas production figures are about 2 TCF/year too high (1 million bbl/d oil equivalent). The administration is not planning on Alaskan gas by 1985, and GAO does not believe that coal gasification is far enough on its way to expect a contribution from that source. The difference between the administration's forecast and the GAO projections cannot be made up from other domestic gas sources, according to GAO, and, therefore, more oil or gas will be imported (or increased conservation).

LNG IMPORTS

The administration is forecasting that LNG imports will decrease if the plan is implemented from 1.2 TCF without the plan to 0.6 TCF with the plan in 1985. This is based on the assumption that the market intervention and regulatory features of the plan will limit natural gas demand in the industrial sector and the supply thus "freed up" will be consumed in the residential sector, thereby obviating the need for additional LNG imports. There appears to be an assumption that natural gas will be demand limited in 1985, which is difficult to understand given its high value from a handling and environmental standpoint, coupled with the fact that the administration would keep the price of natural gas below the price of other fuels. GAO believes that the estimate of LNG imports of 0.6 TCF in 1985 is unrealistically low in the absence of further Government initiatives, such as import quotas for natural gas. In 1976, imports were about 0.5 TCF and current industry proposals already total more than 1.2 TCF.

COAL

GAO supports the administration's goal of expanding coal development without endangering the environment However, in the near term, GAO is not convinced that the goal can be met without recognizing the need for energy and environmental tradeoffs. In the long term, assuming an aggressive and successful coal research and development program, the need for tradeoffs may be substantially diminished.

It appears unlikely that U.S. coal production will reach 1 billion tons in 1985, the level the administration believes it can achieve without the plan, let alone its goal of 1.2 billion tons with the plan. GAO has listed numerous constraints on the development of 1 billion tons of coal by 1985. Some of the coal slurry pipelines, labor problems, health and environmental constraints on production and utilization.

COAL CONVERSION

The administration's coal plan is based on: (1) a coal conversion regulatory policy, (2) an oil and gas users tax with a rebate/investment tax credit system, (3) an environmental policy, and (4) a research and development policy.

GAO believes that a conversion policy calling for a ban of natural gas use by utilities and large industrial boilers in 1979 is too soon, but a policy calling for a ban on natural gas use in existing powerplants by

1990 may allow more leadtime than is needed. More studies are needed to determine a better time frame than proposed in the plan. The GAO believes that the Government should set the example by converting its large facilities to coal.

The administration's plan to reduce the ineffectiveness of the current conversion program by shifting the burden of proof to utilities and large industries to show why they are unable to comply, has potential to make the program less complicated to administer. However, if many companies resist complying and file exceptions, FEA (now DOE) may end up with a greater administrative burden than before. This further underscores the need for an analysis of the optimal time frames for conversion. In addition, a company wishing to delay converting to coal can generally count on a lengthy litigation before a denial of an exception is upheld. GAO expresses the need of FEA requiring administrative resolution of the proposed exception within a specific time from the date of application for exceptions. GAO recognizes that judicial delays may still occur.

AIR QUALITY

GAO states that it seems apparent that the expanded use of coal, even to only 1 billion tons, will not take place if all air quality regulations are strictly enforced. GAO believes that further environmental degraadtion is almost inevitable with increased coal use. The larger uncertainties and issues in air quality, together with strip mine issues, leads GAO to question whether the administration's goal for coal can be achieved by 1985 or, for that matter, 1 billion tons by 1985.

NUCLEAR POWER

GAO doubts if the current leadtime between initial licensing and operation of nuclear powerplants of 10 years can be significantly reduced. In view of the built-in delays, GAO believes that nuclear power capacity by 1985 will be about 0.6 million b/d oil equivalent short of the administration's goal.

ALTERNATIVE ENERGY SYSTEMS

GAO has no major disagreement with the administration on its projections of the contribution alternative energy systems are likely to make by 1985.

GAO UPDATE OF JULY RESPONSE TO THE NATIONAL ENERGY PLAN

On October 14, 1977, the Comptroller General, Elmer Staats, wrote a letter to the President of the Senate and the Speaker of the House of Representatives. In the letter the Comptroller General explains that a fresh analysis of likely oil production in the United States has resulted in a more pessimistic assessment of U.S. energy production.

The GAO concluded that crude oil production in the range of 8 to 9 million b/d is a more realistic estimate than the 10.6 million b/d projected for 1985 in the national energy plan. According to the oil production estimates in the national energy plan, 8.6 million b/d of the 10.6 million b/d would have to come from the lower 48 States. This would require a finding rate of new fields at almost twice the rate we have ever experienced since 1946. Based on this past experience, the GAO has serious doubts whether domestic output in 1985 can achieve a level as called for in the national energy plan. Prudent planning would put oil production in the 8 to 9 million b/d range rather than the 10.6 million b/d output in the national energy plan. Only if very large new fields were discovered could higher levels of production be attained. While this is still possible, the GAO beileves this is too uncertain for planning purposes.

In view of the lower GAO estimate of 1985 oil production. the additional production shortfall would result in oil imports of up to 12.9 million b/d to meet 1985 energy demand (see table).

Estimated oil imports, 1985

	MMB/D
Administration's goal for oil imports in 1985	6.0
Administration's estimate of reduction due to voluntary actions	+1.0
Our estimate of additional imports required to compensate for lower amounts of domestic production for: [1]	
Coal	+2.3
Natural gas	+1.0
Nuclear power	+.6
Our estimate of reduced oil imports as a result of higher imports of liquefied natural gas [1]	−.6
Subtotal; oil imports estimated in our July report	10.3
Estimated shortfall in domestic oil production	+1.6 to +2.6
Total estimated imports	11.9 to 12.9

[1] See GAO Report EMD–77–48 for details.

U.S. CONGRESS, OFFICE OF TECHNOLOGY ASSESSMENT, "ANALYSIS OF THE PROPOSED NATIONAL ENERGY PLAN," WASHINGTON, D.C., JUNE 1977

OTA agrees with the emphasis on conservation in the 1977 NEP, because it offers the greatest potential for keeping U.S. dependence on imported energy within the limits imposed by world production capability and demand by the rest of the world.

The plan's principle that energy should be priced at replacement cost is fundamental to achieving the needed conservation levels. The strategies and tactics proposed by the plan are, for the most part, moves in the right direction to increase energy use efficiency and expand the use of more abundant domestic energy supplies.

Certain areas of the demand side of the equation need strengthening. (1) The plan depends largely on the creation of demand to stimulate supplies (in particular coal, where the conversion program is to bring forth the needed coal use). (2) The plan's proposals could continue existing price distortions and reduce the effectiveness of price signals in motivating commerce to conserve energy. (3) The plan does not adequately coordinate its conservation and conservation goals with the need for research and development on more efficient ways to use energy, both in the near term and the long run. The 1985 projections for energy demand given by the plan appear achievable in most cases and may actually underestimate the potential energy savings, although uncertainties exist in some sectors.

Demand projections in the plan for the industrial sector are much higher than what will occur; demand in the residential sector is reasonable; demand in the ultilities sector could turn out to be higher or lower; and demand in the transportation sector is uncertain, but the goal can be met.

COAL CONVERSION OF UTILITIES NOW BURNING GAS

May be difficult because of the concentration of more gas-burning utilities in Texas, Louisiana, Alabama, and Oklahoma. It may be too much of a burden for utilities in those States to convert, and they may instead pay the proposed gas tax in NEP.

Industries may not choose to convert to coal but instead may shift to electricity to overcome the many problems related to coal utilization. This is not necessarily bad, but it is not the intention of the plan.

SUPPLY

OTA agrees with the gravity of the world energy situation and believes that the plan is a comprehensive and generally consistent set of policies that will permit the United States to begin to manage its energy supplies before conflicting claims on diminishing world oil supplies reach crisis proportions.

The plan is said to be a major move in the right direction. It can be improved with adjustment in detail but not in scope. The plan acknowledges the hard energy choices the United States must make and the high cost of those choices. The plan correctly emphasizes that cheap and abundant energy is a thing of the past. One of its most important messages is that even if the United States could afford to import unlimited amounts of oil indefinitely unlimited supplies of oil simply do not exist anywhere in the world. The plan accurately perceives this in the basic supply goal, which is to begin to shift the country away from near total reliance on oil and gas toward the use of energy supplies whose resource bases have a potential for growth.

The levels of supply projected by the plan represent the upper limits of capacity and supplies of all fuels are likely to fall below the plan's goals. There is no room for error or delay in any one of the sources of supply. Considering the past 7 years of performance in developing new energy supplies, it is unlikely that all elements of the plan will fall into place precisely on schedule.

Production of oil could fall short of the plan's goals by as much as 0.5 to 1.5 million bbl/d; natural gas production may also fall short by the equivalent of 0.5 to 1.5 million bbl/d of oil; coal production could be 200 million tons per year less (2.4 million bbl/d oil equivalent); and, nuclear power could produce 15 percent less energy (0.6 million bbl/d oil equivalent) than the plan projects.

The plan contains no contingency plans for stimulating production of energy or further reducing consumption in the event of slippage in one or more sources. The incentives proposed by the national energy plan concentrate more on switching demand than on encouraging higher rates of production.

The plan fails to acknowledge that there will be inevitable conflicts between environmental protection and increased energy production and use. It should face that possibility squarely and propose mechanisms for resolving the conflict. If energy production falls short of the plan's forecast, it is more likely to be caused by environmental and regulatory conflicts than by lack of available resources, capital, or manpower. For example, between one-fourth and one-third of the oil and gas which the plan anticipates will be produced domestically has not yet been discovered. Most of it is in the frontier areas offshore and in Alaska. But envirormental objections and proposed new OCS laws could add years to the time when new leases might be producing.

Nuclear power is another area where the administration may be too optimistic. Accelerating the licensing process for new powerplants, deals with only one factor in a process which now makes the leadtime for nuclear powerplant as long as 12 years. Environmental problems, public acceptance and State permits for siting are other factors causing delays. The plan leaves open the question of potential conflicts between air quality and a virtual doubling of the use of coal as an energy source. The plan is designed to encourage burning of high-sulfur eastern coal by requiring best available technology. Not only utilities, but also coal-burning industrial boilers would need scrubbers. But most industrial plants are built near urban areas where air pollution already exceeds Federal standards. Delays in the conversion process may in turn reduce demand and retard the increased production of coal which the plan anticipates. Delays in coal production will in turn increase reliance on oil.

The plan projects growth in the domestic oil and gas production, but without discoveries of new oil fields, oil production could decline as much as 25 percent and gas production as much as 45 percent. To achieve the plan's production goals, oil and gas discovery rates must double the industry's finding experience over the past 15 years. Most of this must come from Alaska and the Outer Continental Shelf. The OTA questions if the plan's pricing policy provides enough incentives to encourage exploration and development leading to the required production.

Solar: While commending the plan for the emphasis on solar energy, OTA questions whether the plan's goal of installing solar energy equipment in 2.5 million homes by 1985 can be realized.

Beyond 1985: The plan is silent in post-1985 energy development: Specifically it does not relate short-term plans to long-term energy demands and supply patterns. Will the plan provide a strong foundation for developing new energy technologies and resources after 1985? Domestic oil and gas supply—even if they reach the plan's target by 1985—will almost certainly decline after 1985.

OTA suggests plans to direct capital to programs to accelerate synthetic oil and gas that can replace declinig oil and natural gas production after 1985. By 1985, coal will provide 29 percent of U.S. energy if the plan succeeds. Will this trend continue after 1985? If so, the plan should address this.

Achievement of the plan by 1985 will require high investments of capital, large manpower training programs, and expensve research and development, particularly on clean-burning technologies for coal. Can similar requirements of capital, manpower, and research be superimposed on the economy after 1985 without straining the economy?

The breeder decision was based on assumptions of ample supply of uranium. If this proves to be wrong, it will have a serious effect on nuclear power development.

Finally, OTA believes that the impact of the plan in the economy and employment are minor, but the consequences of failure to act may be far more severe. Close cooperation between the Federal and State governments is called for to help shape and implement policy that the plan proposes.

JOHN H. LICHTBLAU, U.S. OIL SUPPLY AND DEMAND TO 1990, NEW YORK, OCTOBER 1977 [1]

ASSUMPTIONS

Lichtblau's forecast of U.S. energy demand and supply through 1990 is based on the following assumptions:

1. The United States real GNP will grow near the historic rate of 4 percent per year from 1976 to 1980 but will decline significantly—to 3.2 percent—thereafter.
2. Over the entire 14-year period through 1990 the energy/GNP ratio will decline from 1.10 for 1965/73 to 0.71 for 1976–90. Energy growth rates will decline from 2.7 percent in the 1976–80 period to 2.4 percent and 2.1 percent in the 1980–85 and 1985–90 periods respectively. The latter will be about half the historic growth rate.
3. Foreign crude oil prices will remain approximately stable in real terms throughout the period and the delivered cost of foreign gas will be about equal with that of foreign oil on a Btu basis.
4. Some form of continued price control of U.S. crude oil enhanced recovery, shale oil and newly discovered oil.
5. Prices for domestic gas supply on parity with oil prices by 1980. Prices for old gas will continue to be controlled. Average price of natural gas will remain below the equivalent cost of oil.
6. Coal prices will increase somewhat in real terms but remain below the cost of oil.
7. Additional conservation and additional substitution resulting from governmental mandates or incentives.

DEMAND

Demand will increase, but at slower pace than during the past, and there will be a switch from oil to other energy sources such as coal. Lichtblau believes, however, that these trends will develop more slowly than the national energy plan does.

The study agrees that the energy/GNP ratio will decline from the historic level of over 1, but not to a ratio of about 0.5 over the next 8 years.

There will be some shift in oil demand by the consuming sector. The transportation and residential sectors will continue to remain the two principal outlets for oil, but the share of both will decline from a combined level of 72 percent of total oil sales in 1976 to 66 percent in 1985 and 65 percent in 1990. The offsetting increases will be registered mainly in sales to the industrial sectors. Total primary energy demand is projected to rise from 73 quads in 1976 to 92.9 quads in 1985 and 103.1 quads in 1990.

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[1] John Lichtblau is president of the Petroleum Industry Research Foundation, New York.

SUPPLY

Total U.S. oil and natural gas liquids production would increase from 9.7 million barrels per day in 1976 to 10.8 million barrels per day in 1985 and 10.4 million barrels per day in 1990. Synthetic oil production contribute 0.3 million barrels per day in 1985 and 0.8 million barrels per day in 1990.

Of the total of 10.4 million barrels per day of oil production in 1990 about 4 million barrels per day would come from the Lower 48 States onshore—6.8 million barrels per day in 1977—and 2.9 million barrels per day from all offshore areas. Enhanced recovery would add 1 million barrels per day—tertiary recovery—and the Alaskan North Slope would produce 2.1 million barrels per day.

Domestic natural gas supply is estimated to decrease from 19.2 quadrillion Btu's—quads—in 1976 to 17.3 quads in 1980; decreasing thereafter to 16.5 quads in 1985 and 16.1 quads by 1990—1 quad equals 1 trillion cubic feet.

Coal use is expected to almost double, from 13.8 quads in 1976 to 25.2 quads in 1990. In 1985, coal use is estimated at 21.2 quads.

Nuclear energy is projected to grow from a capacity of 41 gigawatts in 1976 to 118 gigawatts in 1985 and 185 by 1990.

IMPORTS

Oil and natural gas imports are expected to fill the gap between total U.S. demand and domestic supply of energy.

Natural gas imports are projected to increase from about 1 quad in 1976 to 2.6 quads in 1985 and 3.2 quads in 1990. About one-half of the natural gas imports will be in the form of pipeline gas; the remainder will be LNG.

Crude oil and product imports are estimated to grow from 7.3 million barrels per day in 1976 to 9.6 million barrels per day in 1985 and 10.1 million barrels per day by 1990. Product imports are expected to rise from 2 million barrels per day in 1976 to 2.6 million barrels per day by the middle 1980's. Most of the increased product imports will come in the form of residual fuel oil and natural gas liquids.

U.S. ENERGY SUPPLY/DEMAND, 1965–90

[In quadrillions of Btu's]

	1965	1973	1976	1980	1985	1990
Supplies:						
Natural gas [1]	16.1	22.5	20.2	18.5	19.1	19.3
(Of which imports)	(0.5)	(1.0)	(1.0)	(1.2)	(2.6)	(3.2)
Oil and other liquids [2]	23.2	34.9	34.9	40.5	42.4	43.6
(Of which imports)	(5.3)	(13.3)	(15.6)	(19.9)	(20.5)	(21.5)
Coal [3]	11.9	13.3	13.8	16.4	21.2	25.2
Nuclear		.9	2.0	3.9	6.9	11.6
Other	2.1	3.0	3.0	3.1	3.3	3.4
Total primary energy demand	53.3	74.6	73.9	82.4	92.9	103.1
Gas imports:						
Pipeline	.5	1.0	1.0	.8	1.3	1.4
Liquified natural gas				.4	1.3	1.8
In million barrels daily	2.5	6.2	7.3	9.3	9.6	10.1

[1] Includes conventional domestic production and coal synthetic natural gas production.

[2] Crude oil, natural gas liquids, and shale oil production.

[3] Domestic coal consumption, excluding coal used for synthetic natural gas.

ARNOLD SAFER, INTERNATIONAL OIL REVISITED: COULD THE EXPERTS BE WRONG?, "THE ECONOMIC VIEW FROM WALL STREET," NEW YORK, DECEMBER 1977.

Major thesis.—No major oil shortage is expected between now and 1985. Current oil surplus conditions are expected to continue at least through 1982. Safer assumes low economic growth rates for Europe and Japan, and is very optimistic on non-OPEC supply. As a result of these developments, oil prices may not rise at all in the years ahead because of the world oil surplus. Hence, the United States is in a position to develop policies to dilute OPEC price-setting powers. The United States should change the commercial mechanism by which oil is imported. Without this change, it is unlikely that oil consumers will benefit optimally from the improved market conditions.

ASSUMPTIONS ON WHICH THE SAFER STUDY IS BASED

Economic growth.—Real economic growth rates for the United States are in line with official U.S. Government forecasts of about 4 percent per year through 1980; Western European and Japanese economic growth rates for the same period are estimated at respectively 2.5 percent and 5 percent. Safer projects a recession in 1980–81 followed by a recovery in 1982.

Energy growth.—Not much is said about demand elasticity or interfuel substitution. Safer assumes an annual oil consumption growth rate of 3.5 percent through 1980. Following the 1980–81 recession, oil consumption growth rates decline by 3.5 percent in 1981. Oil consumption growth rates increase again in the following years—4 percent in 1982; 3.5 percent in 1983; and 3 percent in 1984–85.

DEMAND

The study projects free world oil demand to grow gradually through 1980. Thereafter, oil demand would diminish due to a projected economic recession, and grow again in the period from 1982–85 (see table I). By 1985, free world oil demand will be at about 60.5 million barrels per day, or about 10 million barrels per day higher than current demand. Modest oil demand is projected for Japan and Western Europe. U.S. oil consumption projections for the early and middle 1980's are higher than estimates by the Department of Energy, but they are within the ranges of most projections.

The principal difference between the Safer study and most other studies is the inclusion of a recession in 1980–81. Most studies project annual growth rates which average out high- and low-growth years.

SUPPLY

The Safer study is very optimistic on non-OPEC oil supply (see table II). In particular the oil production estimated for the United States and Western Europe are considerably higher than other sources. Adjusting United States and Western European supplies for more generally accepted estimates, non-OPEC free world oil production would be about 3.5 million barrels per day lower by 1985 than the data in table II. Safer also believes that the Communist countries will continue to increase their oil exports from 1.2 million barrels per day in 1978 to 1.6 million barrels per day in 1982. In total, available non-OPEC oil supply in the early 1980's is about 5 million barrels per day above estimates by the Department of Energy.

Safer believes that recent Government and other projections of declining oil reserves are only the latest scare story on declining oil resources. Such fears were also expressed in 1914, 1926, 1939, and 1949; and each time the Government proved wrong. This comparison, however, assumes that exploratory research has not much advanced beyond the 1949 level, and that is definitely not true.

Non-OPEC oil supplies for 1985 are estimated between a low of 25 and a high of 35 million barrels per day. The optimism about high non-OPEC oil production is based on the following:

—1975–77 reserve additions were 5 billion barrels larger than oil consumption;

—High expectations for future North Sea and Mexican reserve additions;

—Total resource base of 1.5 billion barrels, or a world resource/consumption ratio of 65 years;

—Relatively low demand due to sluggish economy;

—Higher gas drilling likely to reduce further gas production decline. This will slow down substitution of oil for gas.

OPEC OUTLOOK

Because of the above projections of world demand and non-OPEC supply, demand for OPEC oil will continue to decline, from 30 million barrels per day in 1977 to 26 million barrels per day in 1982, and between 25.5 and 35.5 million barrels per day by 1985. Hence, OPEC's proportion of world supply would be reduced from about 60 percent in 1977 to less than 50 percent in 1982.

Safer maintains that the lower demand for OPEC oil could have serious repercussions for OPEC. The cartel would have a difficult time in maintaining its internal cohesion and could become more susceptible to arm's-length bargaining over crude oil prices. He suggests that the U.S. Government give serious consideration to altering the commercial mechanism by which oil is imported into the United States. One mechanism to be considered is a neutral market pricing system, possibly regulated by representatives of both consuming and producing nations.

TABLE I.—PROJECTED WORLD OIL CONSUMPTION [1]

[In million barrels per day]

	Actual		1977 estimate	Forecast					
	1973	1976		1978	1979	1980	1981 [2]	1982	1985
United States	17.3	17.4	18.4	19.1	19.8	20.5	20.2	21.4	23.5
Canada	1.7	1.8	1.8	1.9	2.0	2.1	2.0	2.1	2.3
Western Europe	14.5	14.3	14.1	14.3	14.8	15.1	14.2	14.9	16.3
Japan	5.0	4.8	5.0	5.2	5.6	5.7	5.3	5.5	6.0
Other	8.8	10.1	10.2	10.5	10.8	11.1	11.0	11.1	12.4
Total	47.3	48.4	49.5	51.0	53.0	54.5	52.7	55.0	60.5

[1] Excludes Communist countries. Historical data from American Petroleum Institute; projections by Irving Trust Co.

[2] Year of projected world recession.

TABLE II.—NON-OPEC SUPPLIES [1]

	Actual		Estimated	Forecast				
	1975	1976	1977	1978	1979	1980	1981	1982
Western Europe	0.6	0.9	1.8	2.5	3.1	4.1	4.7	5.0
Mexico	.8	.9	1.1	1.4	1.7	2.0	2.1	2.2
Alaska			.2	1.1	1.4	1.7	1.8	2.0
United States (Lower 48)	10.5	10.4	10.4	10.4	10.5	10.6	10.8	11.0
Canada	1.9	1.8	1.8	1.8	1.8	1.4	1.9	1.9
Rest of world [2]	3.4	3.6	4.0	4.2	4.4	4.8	5.1	5.3
Total	17.2	17.6	19.3	21.4	22.9	24.6	26.4	27.4
Net Sino-Soviet Exports [3]	1.0	1.1	1.2	1.2	1.3	1.4	1.5	1.6
Total	18.2	18.7	20.5	22.6	24.2	26.0	27.9	29.0

[1] Includes crude oil, condensate, natural gas liquids, and refining processing gains.

[2] See appendix for rest of the world breakdown.

[3] Net Sino-Soviet exports are gross exports to the West minus imports from the West, largely by Eastern Europe.

TABLE III.—DISTRIBUTION OF OPEC PRODUCTION ACTUAL AND PROJECTED

[In millions of barrels per day]

					Forecast 1980–82 (3-yr average)			
	Actual 1976		Estimated 1977		Case A		Case B	
	Amount	Percent	Amount	Percent	Amount	Percent	Amount	Percent
Large population group:								
Algeria	1.0	3.2	1.1	3.7	1.1	4.2	1.1	4.2
Ecuador	.2	.6	.2	.7	.2	.8	.2	.8
Gabon	.2	.7	.2	.7	.2	.8	.2	.8
Indonesia	1.5	4.9	1.7	5.7	2.0	7.6	2.0	7.6
Iran	5.9	19.3	5.5	18.3	6.5	24.7	3.0	11.4
Iraq	2.3	7.5	2.4	8.0	4.0	15.2	3.5	13.3
Nigeria	2.1	6.8	2.2	7.3	2.5	9.5	2.0	7.6
Venezuela	2.3	7.5	2.2	7.3	2.5	9.5	2.0	7.6
Total	15.5	50.5	15.5	51.7	19.0	72.2	14.0	53.2
Small population group:								
Libya	1.9	6.3	2.1	7.0	1.6	6.1	1.9	7.2
Kuwait	2.2	7.1	1.8	6.0	1.5	5.7	1.9	7.2
United Arab Emirates and Qatar	2.4	8.0	2.4	8.0	1.6	6.1	2.1	8.0
Saudi Arabia	8.6	28.1	8.2	27.3	2.6	9.9	6.4	24.3
Total	15.1	49.5	14.5	48.3	7.3	27.8	12.3	46.7
Total OPEC	30.6	100.0	30.0	100.0	26.3	100.0	26.3	100.0

W. J. Levy Consultants Corp., an Assessment of U.S. Energy Policy, September 1976—International Assessment

Free world energy consumption is projected to increase from 78.6 million barrels per day oil equivalent to about 119.0 million barrels per day oil equivalent. The largest part of the increase was estimated to take place in the United States—about 14.5 million barrels per day between 1975 and 1985—followed by Western Europe—11.8 million barrels per day increase—and Japan—7.3 million barrels per day increase.

Oil imports would rise in all major areas, but the rate of increase would be fastest in the United States.

OPEC export requirements were estimated at 41.9 million barrels per day in 1985, which would mean that total OPEC production would have to be close to 46 million barrels per day in 1985.

ENERGY CONSUMPTION, OIL CONSUMPTION, AND OIL IMPORTS/EXPORTS AMONG MAJOR AREAS—1975 AND 1985 PROJECTED

	1985	1975	1975–85
Energy consumption (millions of barrels daily oil equivalent):			
United States	48.7	34.2	+14.5
Western Europe	35.0	23.2	+11.8
Japan	14.2	6.9	+7.3
Developing countries [1]	21.1	14.3	+6.8
Total energy consumption free world	119.0	78.6	
Oil consumption (millions of barrels daily):			
United States	23.7	16.3	+7.4
Western Europe	19.6	13.1	+6.5
Japan	9.4	4.8	+4.6
Developing countries [1]	12.1	7.2	+4.9
Total free world oil consumption	64.8	41.4	
Oil imports (millions of barrels per day):			
United States	10.7	5.8	+4.9
Western Europe	14.6	12.4	+2.2
Japan	9.4	4.9	+4.5
Developing countries [1]	6.9	3.7	+3.2
	41.6	26.8	
OPEC exports (millions of barrels daily)	41.9	25.9	+16.0

[1] Includes some non-OECD industrialized countries such as South Africa and excludes OPEC members.

THE CONGRESSIONAL RESEARCH SERVICE REPORT

This study, undertaken by the Congressional Research Service, analyzes in great detail U.S. energy demand and supply through the year 2000. In addition to the usual demand/supply analysis based on economic factors, the study considers the impacts on demand and supply of environmental and institutional concerns and actions. Data on European and Japanese energy demand and supply were based on updated OECD energy studies.

METHODOLOGY

On the demand side, three cases have been developed: an optimistic, a pessimistic, and a base case. The optimistic case is based on economic assumptions derived from the DRI long-term trend forecast of 1976 in conjunction with a modified version of the November 1976 energy control forecast.

Supply scenarios were not based on the DRI model, because the CRS supply forecasts indicated supply constraints on domestic oil, natural gas, and coal, which make the DRI supply projections unattainable. Oil supply figures are based on: (a) responses to an extensive CRS questionnaire sent to the 15 largest oil and gas producing companies in the United States. The supply forecast in the base case is based on the mean of the responses of the companies; (b) the base case supply data were compared with oil reserves and resources in the country, and the effort required to achieve projected production. Natural gas production projection were arrived at in the same fashion. Nuclear capacity projections are based on assumptions of licensing schedules. Coal supply projections are based on annual growth rates deemed possible after a detailed analysis of production and consumption constraints.

ASSUMPTIONS

The optimistic and base cases project economic growth rates averaging 3.5 percent per year through 1990. The more pessimistic scenario projects growth interruptions, resulting in average GNP growth rates of 3.4 percent per year. Unemployment ranges from 5.4 to 5.7 percent throughout the next 15 years. Energy prices are projected to rise, with decontrol for new natural gas, decontrol of oil in 1979—low growth scenario only—resulting in a rise in the real price of 50 percent over the 1976 price by 1990. Coal prices are projected to remain at $18.50 per ton; natural gas is projected to reach $2.20 per kilowatt hour. The demand scenario is based on price increases only; no effort was made to include the effect on energy taxation.

ENERGY DEMAND

Under the above assumptions, energy demand in the United States is projected to rise from 74 quadrillion Btu's—quads—in 1976, to between 91.2 and 98.4 quads in 1985, and between 104.5 and 113.4 quads in 1990. The reference case estimates demand at 94.8 quads in 1985 and 108.9 in 1990.

The quoted figures are for primary energy; conversion losses range from 24.2 to 24.3 quads in 1985, and from 29.0 to 29.9 quads by 1990. Broken down by sector, energy demand for 1985 and 1990 is estimated as follows:

U.S. ENERGY DEMAND BY SECTOR

[Ranges—in quads]

Sector	1976	1985	1990
Household and commercial	18.8	15.0–20.2	18.1– 23.5
Industrial	21.2	29.9–32.2	35.2– 37.3
Transportation	19.3	21.2–21.7	22.2– 22.7
Final demand	59.3	67.0–74.1	75.5– 83.5
Conversion losses	14.7	24.2–34.3	29.0– 29.9
Gross demand	74.0	91.2–98.4	104.5–113.4

The study does not assume energy taxes in either one of the three demand scenarios. However, the authors of the demand chapter agree that a gradually escalating Btu tax would reduce demand. For example, a $1.35 per million Btu tax by 1990 would result in a 2 percent per year growth rate between 1976 and 1990. The economic impact of reduced energy use is dependent upon the flexibility of the economy. If capital, labor, and other materials can be easily substituted for energy, GNP would only be 0.5 percent below the reference case. If these substitutions cannot be made, GNP would be 2.4 percent less.

The reference case tends to fall toward the low end of a range of energy forecasts made by others, although it is difficult to compare the various projections due to differences in basic assumptions and in time frame, The reference case, which does not include taxes, is about two quads higher than the Carter program with taxes on energy, but the Carter program projects average GNP growth rates of more than 0.5 percent above the growth rates estimated in the CRS study.

ENERGY SUPPLY

Oil and natural gas

Oil production estimates are based on questionnaires sent to the 15 largest oil and natural gas producing companies in the country. The list was taken from Fortune's 500 largest U.S. companies. Companies were asked to provide their best oil and gas supply data under the following assumptions: (1) decontrol of oil after May 1979 (EPCA expires) and no new windfall profit taxes added; (2) decontrol of new natural gas; (3) no changes in the current OCS leasing system; (4) annual average of 1.5–2.0 million acres of Outer Continental Shelf lands leased by the Department of the Interior; (5) No verical divestiture; (6) Naval Petroleum Reserve No. 4 to be leased under similar conditions as OCS lands.

The data obtained in this way were compared with oil and natural gas reserves and resources in the United States, and the mean of the acquired company projections was used in the base case of the CRS oil and natural gas projections. The mean of the company projections was considered reasonable in view of actual oil and gas reserves and projected oil and gas resources as put forward in U.S. Geological Survey Circular 725. Data for oil include natural gas liquids; natural gas figures are for dry gas only (Bureau of Mines definition: "domestic dry gas to domestic use").

U.S. OIL AND NATURAL GAS PRODUCTION PROJECTION, 1976–90 (BASE CASE)

[Oil in millions of barrels per day and natural gas in trillions of cubic feet per year]

	1976		1985		1990	
	Oil	Gas	Oil	Gas	Oil	Gas
Lower 48 States onshore	8.4	15.8	6.5	11.0	5.7	8.8
Lower 48 States offshore	1.4	4.3	1.6	4.5	2.1	5.6
Alaska onshore		0.2	2.0	1.1	2.0	1.5
Alaska offshore	0.2		0.8	0.3	1.6	1.0
Total	10.0	20.3	10.9	16.9	11.4	16.9

The CRS study recognizes that the base case projection would require a significant drilling effort and finding rate, because oil production of 11.4 million bbl/d in 1990 would require a resource base of 102 billion barrels of oil and 243 tcf of natural gas. The total oil resource base is estimated at 160.7 billion barrels (proved reserves of 38.9 billion barrels, the mean figure of USGS Circular 725's undiscovered recoverable resources is 97.8 billion barrels, and the National Petroleum Council estimates another 24 billion barrels can be recovered with the assistance of advanced recovery techniques). The 102 billion barrels is arrived at as follows: A cumulative production of 62 billion barrels is needed to get to 11.4 million bbl/d production by 1990. Assuming current r/p factor of 10, a total resource base of 102 billion barrels is required.

The natural gas figure of 243 tcf is arrived at in a similar fashion: In order to produce 19.9 tcf of dry natural gas in 1985 and 1990, about 19.1 tcf of gross withdrawals are needed in those years. Total cumulative gross withdrawals to achieve a production of 19.1 (gross withdrawals) in 1990 are estimated at 272. Assuming an r/p factor of 10 (current r/p factor) by 1990, 463 tcf of gas will be requred to meet projected production and maintain an r/p factor not lower than today's. In December 1976 reserves were 216 tcf. Hence, 463–216=247 tcf of natural gas (gross withdrawals) will have to be found between 1977 and 1990. The total remaining resource base is estimated at: 216 tcf of proved reserves; 201 tcf of inferred reserves; and 484 tcf of undiscovered recoverable resources (USGS Circular 725, weighted mean). This makes for a total of 901 tcf of natural gas resources.

In view of the large drilling effort projected as a result of decontrol of oil and natural gas, production projections of oil and natural gas for 1985 and 1990 are said to be reasonable under the given assumptions.

CRS also projects a maximum of 0.5 tcf/year of syngas in 1985 and 1.5 TCF from this source by 1990. However, a favorable Government support program would be needed to achieve this target.

Coal

The CRS study is bearish on coal because of the very substantial constraints on both demand and supply of this fossil fuel. Reserves and resources of coal are large enough to support current production of close to 700 million tons for at least 250 years. If the United States decides to speed up coal production to more than double current coal production by the end of the century, the resource could of course be reduced to about 125 years. In any case, this would give the country sufficient time to search for alternative, preferably renewable, energy sources.

CRS has made three projections for 1985–90 (see table 1). Actual production will depend on whether or not the Nation will succeed in removing production and utilization constraints. These constraints are: (1) Lack of sufficient capital because of utilization uncertainties; (2) shortages of manpower and training; (3) inadequate transportation facilities; (4) environmental enhancement measures—their kinds, severity and rigor, timing and requirements; (5) delays in leasing of Federal coal lands; (6) uncertainty about environmental regulations that regulate coal out and thus create uncertainties on the supply side and reluctance to invest; (7) equipment shortages; (8) labor problems; and (9) inclement weather, such as in January/February of 1977.

These and other constraints could severely hamper the administration's goal of producing more than 1,200 million tons of coal by 1985. Coal is still a dirty fuel, which is unwanted as long as oil is around at current or slightly higher prices.

TABLE 1.—U.S. PRODUCTION AND UTILIZATION OF BITUMINOUS COAL AND LIGNITE

[Million tons and quadrillion Btu]

	Million tons		Quadrillion Btu	
	Domestic utilization	Exports	Domestic utilization	Exports
Low:				
1977	610	65	13.2	1.7
1980	640	80	13.2	2.1
1985	760	90	14.9	2.4
1990	1,020	90	19.9	2.4
Median:				
1977	630	65	14.0	1.7
1980	695	80	14.3	2.1
1985	850	90	16.3	2.4
1990	1,135	90	22.2	2.4
High:				
1977	660	65	14.4	1.7
1980	730	80	15.1	2.1
1985	940	90	18.5	2.4
1990	1,250	90	24.5	2.4

Nuclear power

The CRS study maintains that the principal impediment to growth in the nuclear industry between 1977 and 1990 is related to nuclear powerplant licensing by the Federal Government. The study projects that by 1990, U.S. nuclear capacity can be anywhere between 130 and 330 gigawatts, depending on the constraints on this source of power. Other constraints on the growth of nuclear power include the role of nuclear power in U.S. energy policy and the attitude of the President and his administration; opposition by interest groups; uncertainties about capital and operating cost; siting problems and, uncertainty about future uranium supply and enrichment facilities.

Factors which could accelerate the growth of nuclear power include further increases in the price of imported oil, increased prices for coal, and national policy to limit or reduce imports of oil and natural gas.

In particular, widespread opposition to deep—and strip mining of coal can be expected to make nuclear power more attractive to the electricity industry.

TABLE 2.—NUCLEAR POWER CAPACITY: 1977–90

	1977		1980		1985		1990	
	GWe	Btu	GWe	Btu	GWe	Btu	GWe	Btu
Base case	54	3, 240	81	4, 860	131	7, 560	175	10, 560
Low supply	52	3, 120	70	4, 200	100	6, 000	130	7, 800
High supply	56	3, 360	92	5, 520	162	9, 120	222	13, 320
Maximum	56	3, 360	92	5, 520	212	12, 720	332	19, 950

TABLE 3.—FACTORS AFFECTING FUTURE OF NUCLEAR POWER IN THE UNITED STATES

Factor	1990	2000
Industrial capacities:		
Uranium production	No	Maybe.
Uranium enrichment	No	Do.
Fuel reprocessing	No	Do.
Fuel recycle, LWR	No	Do.
Spent fuel storage	No	No.
Terminal waste storage	No	No.
Use of the breeder	No	Yes.
Reactor production	No	No.
Social:		
Public reaction to nuclear power	Yes	Yes.
Public interest group action on nuclear power	Yes	Yes.
Governmental actions:		
Administration's policy for nuclear power	Yes	Yes.
Licensing and regulation: Federal	Yes	Yes.
Licensing and regulation: State	Maybe	Maybe.
Nonproliferation regulation	No	Do.
Further technological development	No	Yes.
Federal legislation	Maybe	Maybe.
Economic:		
Comparative cost of nuclear powerplants	do	Yes.
Comparative cost of nuclear fuel cycle	do	Yes.

Alternative energy sources

Of all alternative sources of energy in the United States, solar energy is projected to expand fastest. Hydropower is not likely to growth much, and geothermal energy is still not expected to make much of a commercial contribution to energy supplies in the United States during the next 15 years. Hydropower, geothermal, and solar energy are projected to expand from about 3 quads in 1975 to approximately 4 quads in 1985 and 5 quads in 1990. Much of the expansion will be from solar power.

BALANCING ENERGY DEMAND AND SUPPLY: 1985–90

Projected domestic demand and supply of energy in the United States for the period 1975–90 is as follows (base case):

TABLE 4.—U.S. DEMAND AND SUPPLY OF ENERGY, 1975–90 REFERENCE CASE

[Conventional units]

Supply	1975	1976	1977	1980	1985	1990
Natural gas (thousand cubic feet per year)	19.2	19.0	18.6	17.4	16.9	16.9
Syngas (thousand cubic feet per year) [1]					(.5)	(1.5)
Naphtha (gas from oil—thousand cubic feet per year)[1]	(.4)	(.4)	(.4)	(.4)	(.3)	(.2)
Petroleum liquids domestic (million barrels per day)	10.0	9.6	9.6	10.4	10.9	11.4
Shale oil (million barrels per day)					.075	.2
Nuclear power (GWe)	36	44	54	81	131	175
Coal (million tons per year) [2]	583	605	630	695	850	1,135
Hydro/Geo/Solar (quads)	3.2	3.0	2.8	3.5	4.0	5.0
Natural gas imports (in thousand cubic feet per year)	.97	.99	.99	1.5	2.1	2.4
Oil imports (in million barrels per day crude oil equivalent)	6.0	7.2	8.1	10.0	11.8	12.9
Oil imports for storage (in million barrels per day) [3]			.1	.4	.3	

[1] Syngas and naphtha are derived respectively from coal and oil. Production of syngas and naphtha is included in crude oil and coal utilization figures.

[2] Domestic utilization of coal. Including coal exports would provide the following total coal production figures: 1975 648,000,000 short tons; 1976, 605,000,000 tons; 1977, 695,000,000 tons; 1980, 775,000,000 tons; 1985, 940,000,000 tons; 1990, 1,225,000,000 tons.

[3] Assumes administration plan to bring total strategic oil reserves to 500,000,000 barrels by 1980 will be passed by Congress. Under current law, 500,000,000 barrels will be in strategic reserves by 1982. If, as proposed, another 500,000,000 barrels will be added to storage by 1985, imports in 1985 may reach about 12,200,000 barrels per day.

TABLE 5.—U.S. DEMAND AND SUPPLY OF ENERGY, 1975–90 REFERENCE CASE

[In quadrillion Btu's]

Supply	1975	1976	1977	1980	1985	1990
Natural gas	19.640	19.399	19.300	17.939	17.424	(17.424)
Syngas [1]					(516)	(1,547)
Naphtha (gas from oil) [1]	(412)	(412)	(412)	(412)	(309)	(206)
Petroleum liquids	19.894	19.460	19.447	21.141	22.258	23.258
Shale oil					157	523
Nuclear power	1.833	2.032	3.240	4.860	7.560	10.560
Coal [2]	12.828	13.749	14.000	14.300	16.250	22.150
Hydro/geo/solar	3.229	3.064	2.800	3.500	4.000	5.000
Total domestic supply	57.424	57.704	58.787	61.740	67.648	78.915
Demand	70.580	73.999	77.000	84.588	94.777	108.940
Total imports	13.156	16.295	18.213	22.848	27.129	30.025
Imports of natural gas	973	990	990	1,547	2,062	2,575
Oil imports	12.183	15.305	17.223	21.301	25.067	27.450
Oil imports (in million barrels daily) crude oil equivalent	6.0	7.2	8.1	10.0	11.8	12.9
Oil storage (in million barrels daily) [3]			.1	.4	.3	
Total oil imports	6.0	7.2	8.2	10.4	12.2	12.9

[1] Syngas and naphtha are derived respectively from coal and oil. Production of syngas and naphtha is inlcuded in crude oil and coal utilization figures.

[2] Domestic utilization of coal. Including coal exports would provide the following total coal production figures: 1975, 648,000,000 short tons; 1976, 665,000,000 tons; 1977, 695,000,000 tons; 1980, 775,000,000 tons; 1985, 940,000,000 tons; 1990, 1,225,000,000 tons.

[3] Assumes administration plan to bring total strategic oil reserves to 500,000,000 barrels by 1980 will be passed by Congress. Under current law, 500,000,000 barrels by 1980 will be passed by Congress. Under current law, 500,000,000 barrels will be in strategic reserves by 1982. If, as proposed, another 500,000,000 barrels will be added to storage by 1985, imports in 1985 may reach about 12,200,000 barrels daily. It is also assumed that another 500,000,000 barrels will be added, to storage between 1980 and December 1985.

U.S. OIL IMPORTS IN THE CONTEXT OF WORLD ENERGY DEMAND AND SUPPLY THROUGH 1990

The CRS study based OECD demand for oil on the recent OECD study on the world energy outlook (Paris 1977). Oil imports for the OECD nations in the OECD study were adjusted for projected shortfalls in nuclear power capacity by 1985. Otherwise, data for OECD Europe, Canada, and Japan (economic growth, energy growth) are similar to those in the 1977 OECD study. CRS also used the same economic data as the OECD study in projecting economic growth in the developing countries, but CRS was less optimistic on interfuel substitution in those countries than the OECD study. Total free world demand for oil is estimated by CRS as follows:

TABLE 6.—FREE WORLD OIL CONSUMPTION, 1960–90

[In million barrels per day]

	Actual				Projected		
	1960	1965	1970	1975	1980	1985	1990
United States	9.8	11.4	14.5	15.8	20.4	22.9	24.9
Canada	.9	1.1	1.5	1.7	2.2	2.5	2.8
OECD Europe	4.1	7.8	12.6	13.5	14.9	18.8	21.4
Japan	.6	1.8	4.0	4.9	6.4	8.6	9.5
Other developed countries	.2	.4	.6	.9	1.4	1.9	2.4
OPEC	1.5	2.2	3.5	1.5	2.3	3.5	4.7
Non-OPEC				5.9	7.2	8.7	10.6
Developing countries							
Total consumption	17.1	24.7	26.7	24.4	54.8	66.9	76.2
Oil storage programs					1.9	1.9	
Total demand including storage					56.7	68.8	76.3

NOTES

On United States, see sections on domestic demand and supply. OECD Europe data for 1980 and 1985 as derived from OECD, "World Energy Outlook," Paris 1977. OECD. Europe demand for 1990 assumes continuation of 1980–85 trends. U.S. figures include natural gas liquids.

Nuclear energy generation is expected to fall short by as much as 8,000,000 bbl/d oil equivalent in 1985 and 5,000,000 bbl/d oil equivalent by 1990.

Oil consumption data for OPEC countries and Japan were derived from various sources, including the quoted OECD study; oil consumption data for developing, non-oil-producing nations are most difficult to assess, and are assumed in this study to increase by 4 percent per year (GNP growth of these nations is expected to grow at slightly more than 6 percent annually).

Productive capacity of the nations of the free world differs, depending on projections of reserve additions in years to come. CRS has estimated free world productive capacity of crude oil and natural gas liquids to range as follows:

TABLE 7.—ESTIMATED FREE WORLD PRODUCTIVE CAPACITY OF CRUDE OIL AND NATURAL GAS LIQUIDS, 1977–90

[In million barrels per day]

	1977	1980	1985	1990
United States	9.5–10.0	9.5–11.3	9.5–12.9	10.1–13.2
Canada	1.7–2.0	1.3–1.9	1.0–1.7	1.5–2.0
United Kingdom	.6–.7	2.0–2.5	2.7–3.0	2.7–4.0
Norway	.4–.6	.9–1.1	1.3–1.4	1.6–1.7
Other Europe	.3–.4	.3–.4	.2–.8	.2–.8
Total, OECD	12-5–13.7	14.0–17.2	14.7–19.8	16.1–21.7
Australia/New Zealand	.4	.4–.5	.4–.5	.3–.4
Non-OPEC LDC's:				
Mexico	.9–1.0	1.3–1.8	2.5–4.0	3.0–5.0
Latin America	1.2–2.0	1.3–2.1	1.3–1.8	1.0–1.3
Middle East	.6–1.6	.6–1.6	1.3–1.9	1.0–1.6
Asia	.5–.8	.5–1.0	.5–1.6	.5–1.4
Africa	.7–1.0	1.1–1.8	1.1–1.8	1.0–1.4
Total, non-OPEC LDC's	3.9–6.4	4.8–8.3	6.7–11.1	6.5–10.7
OPEC:				
Venezuela	2.6–3.0	2.3–2.9	1.9–2.7	1.7–2.5
Ecuador	.2	.2–.3	.3–.4	.3–.4
Indonesia	1.7–1.9	1.8–2.5	1.8–2.5	2.0–2.6
Algeria	1-1–1-3	1.0–1.2	1-2–1.5	.9–1.5
Libya	2.5–2.6	2.2–2.8	2.5–2.8	2.5–2.8
Nigeria	2-1–2.5	2.2–2.7	2.5–2.9	2.5–2.7
Gabon	.2	.2–.3	.3–.4	.3–.5
Iran	6.5–6.8	6.5–7.0	6.0–7.2	4.8–7.2
Kuwait	3.3–3.6	3.0–3.7	3.0–3.9	3.0–3.9
Saudi Arabia	11.1–11.9	14.5–16.0	15.3–20.0	16.0–21.0
Iraq	2.6–3.1	3.4–3.9	4.0–5.0	4.5–5.5
United Arab Emirates	2.1–2.4	2.3–2.8	2.8–3.0	2.5–3.0
Qatar	.6–.7	.6–.7	.6–.8	.4–.6
Total, OPEC	36.4–40.2	40.2–47.0	42.2–53.1	41.4–54.2
Total, Free World	53.2–60.7	59.4–73.0	64.0–84.5	64.3–87.0

TABLE 8.—DEMAND BALANCED SCENARIO OF FREE WORLD SUPPLY AND DEMAND OF OIL AND NATURAL GAS LIQUIDS

	1980	1985	1990
Demand:			
Consumption	54.8	66.9	76.3
Oil storage	1.9	1.9	
Total demand	56.7	68.8	76.3
Supply:			
United States	10.4	10.9	11.4
Canada	1.5	1.4	1.7
United Kingdom	2.1	2.8	3.5
Norway	.9	1.3	1.6
Other OECD Europe	.3	.5	.5
Other developed countries	.4	.4	.4
Subtotal, OECD and other developed countries	15.6	17.3	19.1
Non-OPEC LDC's:			
Mexico	1.6	3.0	4.0
Latin America	1.4	1.4	1.2
Middle East	.7	.9	.9
Africa	1.2	1.4	1.2
Asia	.5	1.0	1.0
Subtotal, non-OPEC LDC's	5.4	7.7	8.3
OPEC:			
Venezuela	2.2	2.1	2.0
Ecuador	.2	.3	.3
Indonesia	1.8	2.0	2.2
Algeria	1.1	1.1	1.0
Libya	2.2	2.2	2.3
Nigeria	2.2	2.4	2.5
Gabon	.2	.3	.5
Iran	6.5	6.7	6.5
Kuwait	1.8	2.1	2.5
Iraq	2.8	4.0	5.5
United Arab Emirates	2.3	2.5	2.5
Qatar	.5	.5	.5
Saudi Arabia	11.8	16.6	20.6
Subtotal, OPEC	34.6	42.8	48.9
Net exports, Soviet bloc	.6	0	0
Net exports, Peoples Republic of China	.5	1.0	0
Net exports, Communist bloc	1.1	1.0	0

The CRS study makes no attempt to project what it believes countries will actually produce. Instead, the study shows a demand-balanced scenario, based on estimated demand for oil and physically available supplies. In a few cases, like Kuwait, limits to actual output are known, and maximum output suggested by official policy has been used in this scenario.

It is clear that Saudi Arabia is counted on to meet any shortfall between world demand and supply for oil at current or slightly higher real prices. The CRS is aware that in the real world there are no shortfalls. If Saudi Arabia decides not to increase production at a level considerably below the suggested production level in the demand-balanced scenario, world oil prices will rise (ceteris parabis), and demand for oil will decline. A new equilibrium between demand and supply of oil will be reached at a new, lower level of output.

The CRS study concludes that if Saudi Arabia decides to meet projected world demand for oil at current or slightly higher real prices, the reserve-to-production ratio (R/P ratio) in that country could fall from 50 years in 1976 to about 17 years by 1990, even if 2 billion barrels per year are added to existing reserves. It is not clear if Saudi Arabia is willing to trade oil in the ground for American and European securities and other holdings.

Finally, the study suggests that in order to achieve anywhere near the oil production levels projected in the study to meet free world demand, the Western World and the producing nations will need to join in an unprecedented effort of cooperation to prevent a breakdown of the international economic system. In order to achieve the degree of interdependence suggested in the study, the study suggests the following potential solutions to optimize Western access to Middle Eastern oil: (1) peace in the Middle East: (2) progress in the north-south talks; (3) solution to investment problems; (4) assistance in producer nations in the area of modernization (technology transfer).

THE MIT WAES REPORT—"ENERGY: GLOBAL PROSPECTS 1985–2000," REPORT OF THE WORKSHOP ON ALTERNATIVE ENERGY STRATEGIES, NEW YORK, 1977

"Energy Global Prospects 1985–2000" is a major energy demand and supply forecast for the next quarter of a century. This comprehensive study is based on contributions from 30 participants from 15 industrialized countries that used 80 percent of the world's energy in 1972. The project director was professor Carroll L. Wilson from MIT's Sloan School of Management. The workshop was designed as a private and informal study group of Government officials, academicians, and businessmen, and the project lasted about 3 years.

The major conclusion of the study is that "world oil will run short sooner than most people realize. Unless appropriate remedies are applied soon, the demand for petroleum in the non-Communist world will probably overtake supplies around 1985 to 1995. This is the maximum time we have: 13 years, give or take 5. It might be less. Petroleum demand could exceed supply as early as 1983 if the OPEC countries maintain their present production ceilings, because oil in the ground is more valuable to them than extra dollars they cannot use. We don't have much time to learn how to replace, or decrease our dependence on, the fuel that for three decades has fed the expansion of Western living standards and the hopes of all nations for material betterment. Time is our most precious resource. It must be used as wisely as energy."

OTHER MAJOR CONCLUSIONS

1. The supply of oil will fail to meet increasing demand before the year 2000, most probably between 1985 and 1995, even if energy prices rise 50 percent above current levels in real terms. Additional constraints on oil production will hasten this shortage, thereby reducing the time available for action on alternatives.
2. Demand for energy will continue to grow even if governments adopt vigorous policies to conserve energy. This growth must increasingly be satisfied by energy resources other than oil, which will be progressively reserved for uses that only oil can satisfy.
3. The continued growth of energy demand requires that energy resources be developed with the utmost vigor. The change from a world economy dominated by oil must start now. The alternatives require 5 to 15 years to develop, and the need for replacement fuels will increase rapidly as the last decade of the century is approached.
4. Electricity from nuclear power is capable of making an important contribution to the global energy supply although worldwide acceptance of it on a sufficiently large scale has yet to be established. Fusion power will not be significant before the year 2000.
5. Coal has the potential to contribute substantially to future energy supplies. Coal reserves are abundant, but taking advantage of them requires an action program of development by both producers and consumers.

6. Natural gas reserves are large enough to meet projected demand provided the incentives are sufficient to encourage the development of extensive and costly intercontinental gas transportation systems.

7. Although the resource base of other fossil fuels such as oil sands, heavy oil, and oil shale is very large, they are likely to supply only small amounts of energy before the year 2000.

8. Other than hydroelectric power, renewable resources of energy—for example, solar, wind-power, wave-power—are unlikely to contribute significant quantities of additional energy during this century at the global level, although they could be of importance in particular areas. They are likely to become increasingly important in the 21st century.

9. Energy efficiency improvements, beyond the substantial energy conservation assumptions already built into our analysis, can further reduce energy demand and narrow the prospective gaps between energy demand and supply. Policies for achieving energy conservation should continue to be key elements of all future energy strategies.

10. The critical interdependence of nations in the energy field requires an unprecedented degree of international collaboration in the future. In addition it requires the will to mobilize finance, labor, research and ingenuity with a common purpose never before attained in time of peace and it requires it now.

Failure to recognize the importance and validity of these findings and to take appropriate and timely action will almost certainly result in a world different from the one on which these projections have been based. Failure to act could lead to substantially higher energy prices as the supply/demand imbalance becomes more apparent—with the depressant effects on the economies of the world and countries. The major political and social difficulties that might arise could cause energy to become a focus for confrontation and conflict.

In addition, the longer the world delays facing this issue the more serious the outcome will be. Even with prompt action the margin between success and failure in the 1985–2000 period is slim. Time has become one of the most precious of our resources. Recognizing the importance to time and the need to response can help us through the period that lies ahead.

WAES METHODOLOGY

WAES developed an approximate model—a simplified conceptual framework—of the real energy world. Its essential feature is that it "decouples," or separates, those global factors not under control of individual, energy-consuming nations from those factors under such national control. WAES covers only the free world; Communist countries are left out because their effect on world energy trade has been relatively small.

The WAES methodology involves seven basic steps: (1) "Energy worlds" that might evolve at the target dates of 1985 and 2000 are defined, based on economic growth and energy price assumptions; (2) Public policy response to the emerging energy situation, characterized as (a) vigorous or (b) restrained. Step two also involves selection of the principal replacement fuels for oil during 1985–2000. WAES selected coal and nuclear; (3) Global assumptions under steps 1, 2, 3, were applied to regional and national scenarios. Thus WAES moved from world and regional economic growth and energy price to national policies and activities; (4) Detailed analysis of national energy demand and supply, producing desired demand (what each nation would like to use at the given price, economic growth and policy assumptions) and maximum potential supply (what could be produced within a given country given the scenario assumptions); (5) Global balancing of demand and supply by WAES. Two kinds of integration are used: unconstrained and constrained.

Unconstrained integration provides information on whether there are sufficient imports to meet preferred fuel demands. "Prospective shortages" (in actuality there are no shortages over extended periods of time, because higher or lower prices will adjust demand to match supply) show where the problems are, their possible size, and how to revise expectations or focus on strategies.

Constrained integration forces substitution of available fuels for shortage fuels on a regional basis. Approximates long-term real world situation, where within certain physical and political constraints, energy decisions are made on a least-cost, most efficient basis. Country scenarios are compared with the overall global energy balance and evaluated in terms of feasibility, consistency and likelihood; (6) If projections point to highly undesirable future, attempts can be made to alter assumptions or by calculating new scenarios; and (7) Addresses major uncertainties outside the framework of the study's main assumptions. This is done to test the impact of such uncertainties on the scenarios.

Finally, the WAES study relied on the World Bank for economic growth and energy growth projections for developing countries. National teams analyzed energy demand and supply for the 13 WAES countries which together consume 78 percent of free world energy consumption and 77 percent of global economic activity in 1975. WAES made its own analysis of energy demand and supply in non-WAES industrial countries as well as supply estimates of non-WAES nations such as OPEC.

GLOBAL SCENARIO VARIABLE

World Energy Price: Based on the price of oil, three alternatives were selected: (a) Constant real price of $11.50 per barrel to 1985; (b) Rising real price to reach $17.25 per barrel by 1985 (arbitrarily chosen to be 50 percent above the constant price); and (c) Falling real price to reach $7.66 by 1985 (this price increased by 50 percent equals the constant price).

FROM 1995–2000

Used only a constant price and a rising price scenario. Instead of oil price, scenario talks about energy price. The constant price is $11.50 per barrel of oil equivalent; the rising energy price is equivalent of $17.25 per barrel of oil through 2000.

ECONOMIC GROWTH

Two assumptions: High and low. In the high case, average economic growth of 6 percent for the free world for 1977–85; the low case assumes 3.5 percent per year for the same period. For 1985–2000, the high case is dropped to 6 percent annually, and the low case to 3 percent per year. The latter allows a slight increase in real GNP per capita.

NATIONAL POLICY RESPONSE

Vigorous or restrained to 1985; vigorous only after 1985. A vigorous energy policy implies strong Government action on both conservation and supply to the greatest degree possible, given national political differences, under the oil price and economic assumptions of the case. A restrained energy policy implies that Government action on conservation and supply is the least that could be expected consistent with price and economic assumptions.

OIL DISCOVERIES AND PRODUCTION LIMITS

Two different scenarios: One assumes gross additions to world oil reserves of 20 billion barrels annually (high); the other assumes reserves additions of 10 billion barrels.

Production limits: OPEC production limits are set at 40 to 45 million bbl/d, which is 10 to 15 million bbl/d higher than 1973 production.

PRINCIPAL REPLACEMENT FUELS: COAL AND NUCLEAR

Other sources, such as shale, solar, wind, and geothermal, are also considered, but their contribution was left to the national teams and did not form an overall scenario variable.

SCENARIO SELECTION

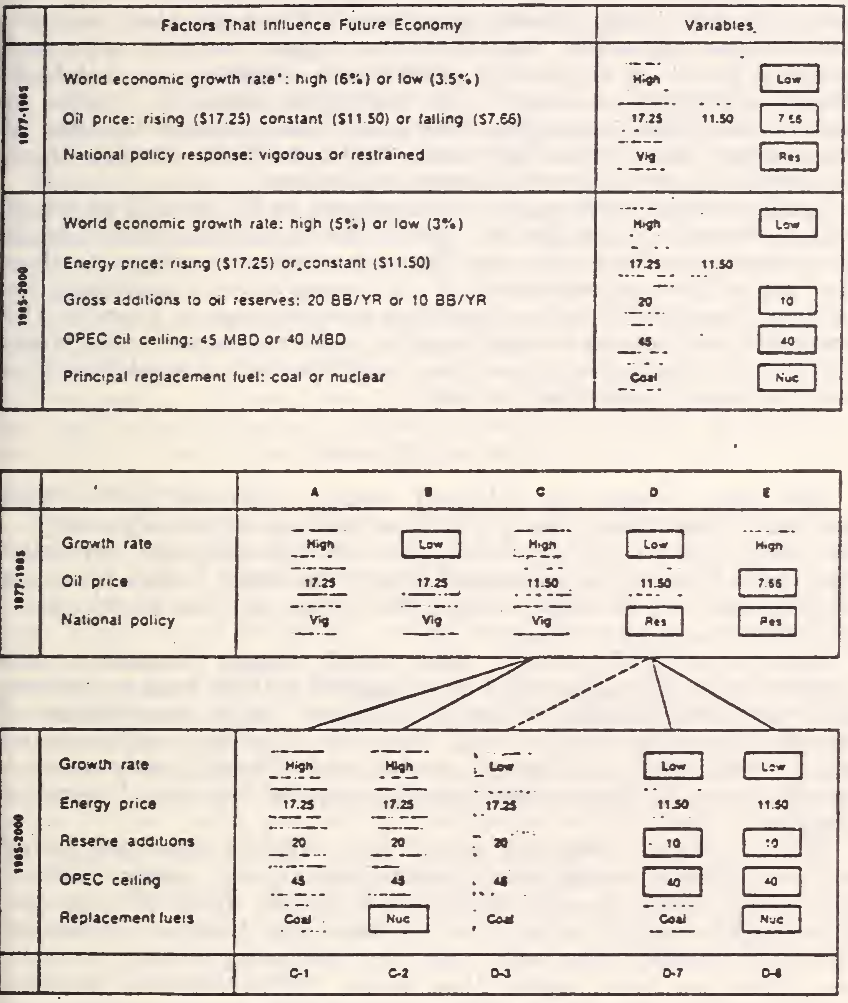
Combination of the above scenario variables yields 48 possible energy futures for 1985 and 32 for the year 2000. Out of these scenarios, five were selected to 1985 and two of these were coupled to the period 1985–2000. Each of these two has a coal/nuclear variant in the latter period, thus giving four scenarios for the year 2000 (most plausible). Cases A, B, C, D, E are treated to 1985; C and D (with one variation each) are extended to 2000 because they appeared more realistic.

The scenario cases and the projection built on them are designed for learning. One can learn quite a bit about basic strategic choices by using these cases, together with the adaptive framework built around them. For example, all four scenarios for the year 2000 point to possible large overall energy and oil gaps, and therefore to the need for vigorous actions beyond those included in the scenario. These gaps will occur with "high-growth/rising price" and "low-growth/constant price" assumptions, and with vigorous policy responses. A "high-growth/constant price" scenario would produce even larger gaps, because there would be less incentive to bring on alternative energy sources than in the "high-growth/rising price" case. Only a "low-growth/rising price" scenario would appear to close the supply/demand gap (see D3 in fig. 1). It helps us learn what kind of adjustments are needed, but the plausibility of some such combinations could be in doubt, according to the authors of the WAES study.

On the demand side of the equation, WAES disaggregated the economy by sectors (69 of them) to cover all energy-using activities in the country. Energy-use efficiency standards were developed to determine how much energy or fuel is needed to do a certain job, taking into account technological changes. All national teams used 1972 as the base year for their projections. Hence, the desired energy demand in the A to E scenarios already reflect technological changes, leadtimes to develop new technologies, and many other engineering and economic variables, in addition to the "vigor" of national policy response. WAES admits growing uncertainty about projections beyond the year 1985, and the study points out that because of these uncertainties, data are not as detailed for the 1985–2000 period.

WAES indicates that there are also a great many uncertainties on the supply side of the energy equation. Some of those uncertainties are:

FIGURE 1.—The WAES Scenario Cases 1972–1985–2000



	Factors That Influence Future Economy	Variables		
1977-1985	World economic growth rate*: high (6%) or low (3.5%)	High		Low
	Oil price: rising ($17.25) constant ($11.50) or falling ($7.66)	17.25	11.50	7.66
	National policy response: vigorous or restrained	Vig		Res
1985-2000	World economic growth rate: high (5%) or low (3%)	High		Low
	Energy price: rising ($17.25) or constant ($11.50)	17.25	11.50	
	Gross additions to oil reserves: 20 BB/YR or 10 BB/YR	20		10
	OPEC oil ceiling: 45 MBD or 40 MBD	45		40
	Principal replacement fuel: coal or nuclear	Coal		Nuc

		A	B	C	D	E
1977-1985	Growth rate	High	Low	High	Low	High
	Oil price	17.25	17.25	11.50	11.50	7.66
	National policy	Vig	Vig	Vig	Res	Res

1985-2000	Growth rate	High	High	Low	Low	Low
	Energy price	17.25	17.25	17.25	11.50	11.50
	Reserve additions	20	20	20	10	10
	OPEC ceiling	45	45	45	40	40
	Replacement fuels	Coal	Nuc	Coal	Coal	Nuc
		C-1	C-2	D-3	D-7	D-8

* The period from 1973 to the end of 1975 is assumed to correspond to actual world economic conditions, with recovery to 1973 levels by the end of 1976 postulated.

National economic studies done under these assumptions, when summed, actually result in global rates of 5.2 and 3.4% to 1985 and 4.0 and 2.8% from 1985 to 2000.

We assume that the scenario variables are approximately independent of each other, within a certain range of values. Any combination of values may, then, be possible and no combination is automatically excluded from consideration.

Source: WAES, "Energy: Global Prospects 1985–2000," New York, 1977, p. 66.

Can we get oil from deeper seas than now, can we economically develop synfuels from coal, what will happen to nuclear power, how soon will solar energy become economical? There are also economic uncertainties, especially about the true capital costs of large and complex pieces of engineering where cost overruns are habitual WAES attempted to identify the maximum potential supplies in each of the WAES countries, taking into consideration the size of the resource base, technology, and capital needs to develop these resources, and constraints on energy development

Finally, demand and supply are integrated to fill "gaps," which, of course, do not exist in the real world. The integration process looks at various ways for developing alternative energy strategies to close the "gaps." Two procedures are used: unconstrained integration, for national "preferred" fuels wherein no consideration is given to the availability of desired energy imports; and constrained integration, which forces the fuel mix to conform to global fuels availability. The latter balances demand and supply.

ENERGY DEMAND

The study focuses on delivered energy—delivered to the final consumer in the form he uses. This is not the same as primary energy—the energy content of fuels before they are processed and converted into forms used by the consumer. Hence, the study looks at heating oil, gasoline, and electricity rather than crude oil, coal at the mine, or natural gas at the wellhead.

Second, the WAES report talks about desired demand or the amounts of energy that would be demanded if there were no restrictions on the availability of energy supplies. Under assumptions of economic growth, energy prices, and the changing coefficients of energy uses, demand scenarios are designed. The approach is not a normative one: It does not touch on the merits of demerits of changing lifestyles.

Third, demand estimates result from explicit assumptions of economic growth, energy prices, and national energy policy. Historic free world energy growth rates of 4.4 percent (1950–72) are not expected to continue in any of the scenarios, because population growth is smaller, efficiencies if used are increasing in many sectors, and prices are much higher than before 1973. Moreover, historic energy growth rates are unrealistic, because high energy growth rates would run against supply problems quickly. The study assumes considerable conservation measures.

REGIONAL ECONOMIC GROWTH PROJECTIONS

Major regions	1977–85		1985–2000	
	High	Low	High	Low
North America	4.3	3.0	3.7	2.6
Western Europe	4.6	2.7	3.3	2.2
Japan	7.9	4.8	4.5	2.7
All industrialized countries	4.9	3.1	3.7	2.5
Non-OPEC LDC's	6.2	4.2	4.6	3.7
OPEC	7.2	5.5	6.5	4.3
Total free world	5.2	3.4	4.0	2.8

SUPPLY OF ENERGY IN THE FREE WORLD

Oil

Potential supplies could be sufficient to meet desired demand up to 1985. Thereafter the gap between demand and supply appears and widens rapidly, giving large deficits in oil suppy in all WAES scenarios by 2000. This prospective gap can be measured as the shortfall between oil imports desired by the major consuming countries and the maximum exports available from oil producing and exporting countries.

Resources constraints are not an immediate problem. WAES states that if all oil-producing countries of the free world allow production to increase to meet demand, limited only by technical factors, oil production will peak and decline before the end of the century. Government policy in oil-producing countries will decide how much oil will in fact be produced. About 80 percent of the free world's oil reserves are in the Middle East, and Saudi Arabia alone controls 27 percent of free world oil reserves. Of total free world cumulative production of 291 billion barrels, 133 have been produced in North America (in particular, the United States) and 139 billion barrels by OPEC. By contrast, the U.S.S.R. and China have only produced 50 billion barrels in total.

Reserve additions

Free world reserve additions averaged 18 billion barrels per year between 1950 and 1970. Reserve additions dropped to an average annual rate of 15 billion barrels between 1970 and 1975. About 60 percent of the free world reserves were found in the Middle East. It is not likely that elsewhere in the world similar vast oil accumulations will be found. About 75 percent of the world oil discovered in the past 100 years lies within 240 large fields (out of a total of 30,000 known fields). Large fields are defined as oilfields containing 500 million barrels or more. Yet in hostile environments like parts of the North Sea and Arctic waters, fields must be at least that size to allow profitable development. It is not likely that having found most of the easy-to-find oil in the free world, genuine new discoveries will maintain even the 15 billion barrel-per-year rate achieved in the period 1970–75. Hence, WAES assumed two scenarios: Successful exploration leading to gross reserve additions on 10 billion barrels per year. Assuming ultimate recoverable oil resources of 1,600 billion barrels (entire world), reserve additions of 20 billion barrels per year would peak around 2000, and drop rapidly thereafter.

Fuel demand by source in the free world

Oil.—44.1 million bbl/d in 1972 to between 73 and 93 million bbl/d by 2000.

Natural gas.—15.1 million bbl/d oil equivalent in 1972 to between 22 and 28 million bbl/d oil equivalent by 2000.

Coal.—14.5 million bbl/d oil equivalent in 1972 to between 21 and 34 million bbl/d oil equivalent by 2000.

Nuclear power.—0.7 million bbl/d oil equivalent in 1972 to between 28 and 39 million bbl/d oil equivalent by 2000.

Hydropower.—5.7 million bbl/d oil equivalent in 1972 to between 9 and 12 million bbl/d oil equivalent by 2000.

Geothermal and others.—0.1 million bbl/d oil equivalent in 1972 to between 2 and 4 million bbl/d oil equivalent by 2000.

Oil use by sector in the free world

Transportation.—14.8 million bbl/d in 1972 to between 28 and 34 million bbl/d by the year 2000.

Industry.—7.9 million bbl/d in 1972 to between 13 and 19 million bbl/d by 2000.

Residential and commercial.—7.1 million bbl/d in 1972 to between 8 and 10 million bbl/d by 2000.

Electricity.—4.9 million bbl/d in 1972 to between 4 and 7 million bbl/d by 2000.

Processing losses.—5.7 million bbl/d in 1972 to about 10 million bbl/d by 2000.

The WAES study suggests that every effort should be made to reserve oil for transportation and petrochemical feedstocks. Other sectors of the economy should move to alternative energy sources. Shifting uses away from oil is as important as conservation, because oil is the scarcest energy source, which serves as the swing fuel in case of shortfalls elsewhere.

ENERGY CONSERVATION

WAES suggests that energy conservation may well be the very best of the energy choices available. Very significant improvements in energy efficiency are projected in the transportation sector, the industrial sector and the residential sector. Energy conservation, says the WAES study, must be a starting point for rational energy policies. It depends on the combined effects of energy prices, Government action, structrual changes in the economy, and the product of innumerable decisions by many users, small and big. Large leadtimes are recognized (a decade for car turnover; 20 to 30 years for most industrial equipment; a century or more for turnover of homes). Conservation must play a central role in global and national strategies to the end of the 20th century and beyond.

The WAES study also suggests that substantial structural shifts in the economies of free world nations could have even greater impact on demand than technical improvements. Participants from some countries have argued that energy growth rates are nearing "saturation"; that is, that the industrialized world is nearing the limits of its capacity to use more and more energy. WAES does not believe that this will be the case prior to the year 2000.

ZERO GROWTH POSSIBLE?

The WAES study suggests that zero or near zero growth in total primary energy use would be extremely difficult to achieve, worldwide, by the year 2000. For the world as a whole it may be more difficult to achieve than is commonly thought, but some countries may approach zero growth by the year 2000. For others, the severe conservation measures and the required structual and institutional changes in the economy would be unprecedented. Zero energy growth is a more realistic target after the turn of the century, according to WAES.

ENERGY DEMAND BY SECTOR: FUTURE FREE WORLD TRENDS

Sectoral shifts in energy consumption are projected. Energy demand for transportation grows from 15 MBDOE (million bbl/d oil equivalent) in 1972 to between 20 and 36 MBDOE by the year 2000. But transportation's share of total delivered energy declines from about 27 percent in 1972 to 25 percent by the year 2000. The decline is most pronounced in the United States (improved fuel economy and shift to diesel engines).

In all regions—except Japan (which is projected to shift away from heavy industries)—there is a substantial increase in the relative shift of energy use in industry, from 37 percent in 1972 to between 40 and 44 percent by the year 2000. The industrial sector is projected to increase comsumption from 21.2 Mbbl/d oil equivalent in 1972 to between 44 and 59 Mbbl/d oil equivalent. Growth in energy consumption in the residential and commercial sector is projected to be slightly lower than growth in the transportation sector: From 15.8 Mbbl/d oil equivalent in 1972 to between 27 and 30 Mbbl/d oil equivalent by 2000. Lower population growth, saturation of some energy uses, and building codes, are offset by the trend toward bigger houses, introduction of appliances in many countries on a large scale, and growth in the service sector of the economy. Finally, processing losses are projected to increase from 23.6 Mbbl/d oil equivalent in 1972 to between 49 and 67 Mbbl/d oil equivalent by the year 2000 (from 26 percent to about 30 percent).

The energy/GNP ratio in the WAES study is estimated to decline from 1.02 in 1965–72, to between 0.82 to 0.87 to the year 2000. Within the industiral world the decline is more than for all of the free world. This is because of relatively greater energy conservation potential in the industrial nations.

Higher energy prices and conservation will reduce consumption, compared to past rates of use.

Demand projections in table 1 represent average annual growth rates in the free world to the year 2000 at between 2.6 and 3.5 percent, compared to 4.4 percent growth from 1950–72. Electricity demand of 3.8–5.1 percent per year—7.5 percent growth are subject to oil import availability at the case price and other assumption. In case of global supply constraints, electricity demand could be lower. Congeneration of electricity might further reduce demand. All scenarios show energy growth, even the lowest estimates. Population growth is projected at a global average of 2.2 percent. Total free world energy demand by the year 2000 ranges from 160-270 million b/d (320-414 Quads).

TABLE 1.—ENERGY DEMAND TOTALS FOR THE WORLD OUTSIDE COMMUNIST AREAS—1972, 1985, 2000

[All numbers are in MBDOE]

		1985		2000			
	1972	C	D	C1	C2	D7	D8
Economic growth		High	Low	High	High	Low	Low.
Energy price		Constant	Constant	Rising	Rising	Constant	Constant.
Policy response		Vigorous	Reserved	Vigorous	Vigorous	Vigorous	Vigorous.
Principal replacement fuel				Coal	Nuclear	Coal	Nuclear.
Fossil fuel demand	50.8	76.2	76.6	117.6	116.7	94.9	93.3.
Electricity demand	5.8	11.0	10.2	20.1	22.9	16.2	18.3.
Delivered (end use) energy demand	56.6	87.2	80.7	137.7	139.5	111.0	111.6.
Processing losses (include international bunkers).[1]	23.6	36.0	33.4	60.2	67.2	48.8	53.9.
Primary energy demand (see fig. 2–2)	80.2	123.2	114.1	197.9	206.8	159.9	165.4.

[1] The energy used in these categories is calculated in the supply-demand integration process (see chapter 8).

Note: Columns may not add precisely, due to rounding.

OIL PRODUCTION THROUGH 2000

If there were no supply constraints, WAES suggest that demand for oil in the free world could rise to between 58 million bbl/d—low growth scenario—and 63 million bbl/d—high growth scenario—in 1985. By 2000, oil demand in the free world could rise to between 75 million bbl/d—low growth scenario—and 93 million bbl/d—high growth scenario. It should be pointed out that even the high growth scenario is considerably below historic annual oil demand growth of 6.2 percent between 1960 and 1972. The WAES high demand scenario calls for a growth rate of 3.4 percent per year in 1985, and 2.6 percent annually from 1985 to the year 2000.

On the supply side, WAES projects a non-OPEC oil production in 1985 of 22 to 24.7 million bbl/d. Hence in order to meet free world oil demand of 63 million bbl/d, OPEC would have to export 36 to 41 million bbl/d. In figure 2 the WAES study show that if OPEC decides to limit oil production to 33 million bbl/d, there will be a shortfall of several million bbl/d. If, however, OPEC increases production to 45 million bbl/d or more, demand and supply will be in balance. By 1990, even with an OPEC production of 45 million bbl/d, there will be a small gap between supply and demand of oil.

Assuming low economic growth, constant energy prices, a restrained Government policy and gross additions to oil reserves of no more than 10 billion barrles per year, there will be a small gap between demand and supply of oil by 1985, if OPEC does not increase production beyond 40 million bbl/d. Under these assumptions, demand will outpace oil supply in 1990, even if there are no other than physical constraints on oil supply from OPEC.

Under optimistic assumptions of economic growth, oil reserve additions, coal developments, and Government policy in general, world oil demand and supply will not balance at a real price of oil 50 percent higher than the current price. Assuming low economic growth to the year 2000, no change in the real price of energy, a restrained Government energy policy, nuclear as the major replacement fuel, and oil reserve additions of 10 billion bbl/year, a large shortage would have developed before the end of the century.

WAES concludes that potential oil demand in the year 2000 is unlikely to be satisfied by crude oil production from conventional sources. In the real world, constraints on oil production are likely to emerge long before the physical constraints become apparent. Hence, WAES concludes possible constraints on oil production by members of OPEC are likely to cause oil supply to peak at the latest sometime around 1990, although lower production limits could bring this date forward into the early 1980's. The end of the era of growth in oil production is probably at the most 15 years away. However, there may be a decade or so of more or less constant oil production after 1990 in which consumers will have to make the adjustments necessary to face a decline in oil supply. It is possible that oil discoveries or recovery factors might be higher than we have assumed, but the effect would be to delay the impact for a few years rather than solve the problem of transition to other fuels. For nations to continue to increase their consumption of oil in the hope that more optimistic estimates might prove to be correct is to run the real risk that the peak in oil production could be brought forward, making the necessary adjustments in energy consumption patterns much more severe.

FIGURE 2.—Oil production, WOCA (case C-1)

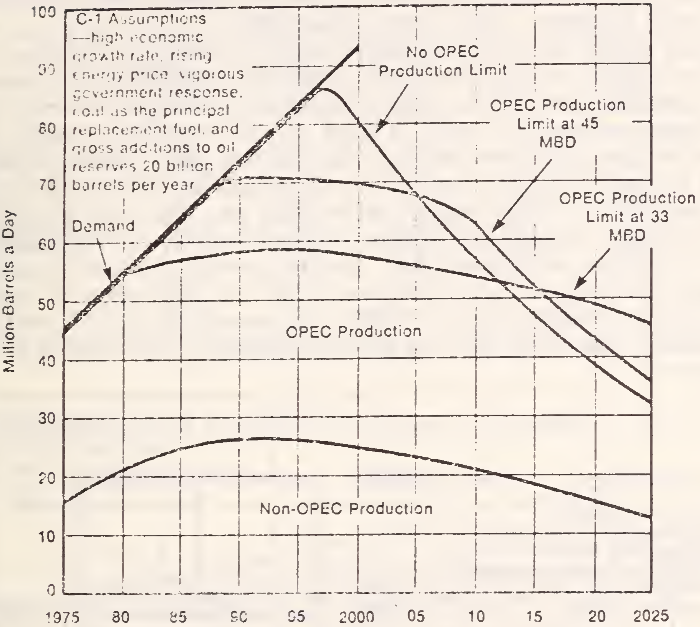
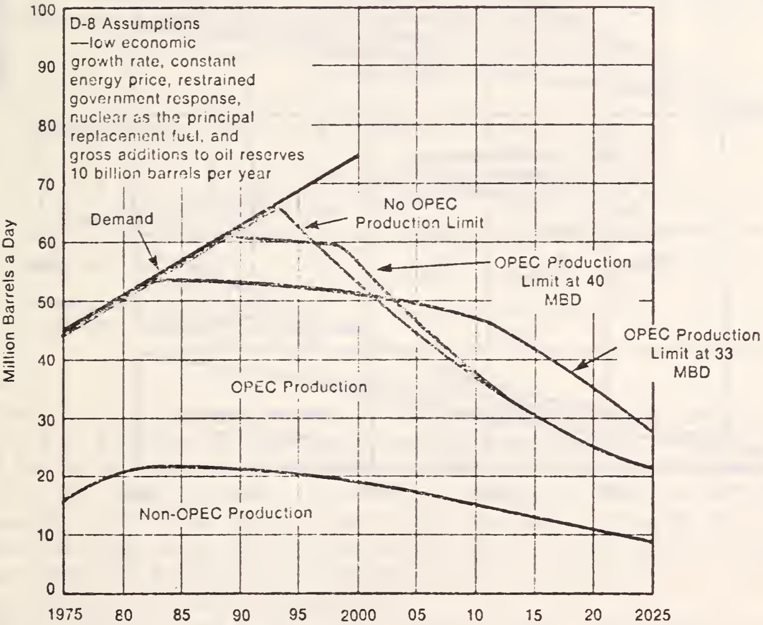


FIGURE 3.—Oil production, WOCA (case D-8)



Natural gas

World reserves and resources are largely unlikely to limit production in the next 25 years. The United States may be the only major gas producing region in the world facing sharp production declines in the more immediate future. The main problems worldwide are related to transportation, distribution, and attitudes of producers toward exports.

The same scenarios C and D used in the preceding section on oil demand and supply was used in the natural gas chapter. The high growth scenario (C) and the low growth scenario (D) are not far apart in projections of OECD imports of natural gas. The high growth case projects higher demand and higher domestic supply in North America, Western Europe, and Japan than the low growth scenario. In addition to higher gas imports in these countries, the high growth case also projects substantially higher OPEC and non-OPEC LDC production for domestic use than the low-growth scenario—see figures 4 and 5 and table 2.

FIGURE 4.—Natural gas supply and demand in WOCA (case C–1)

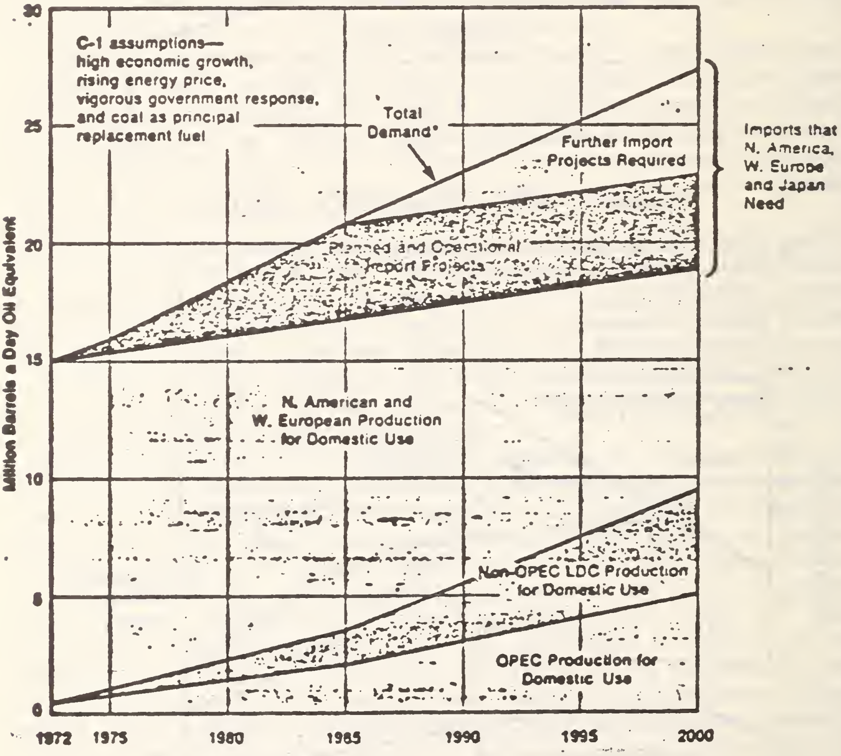
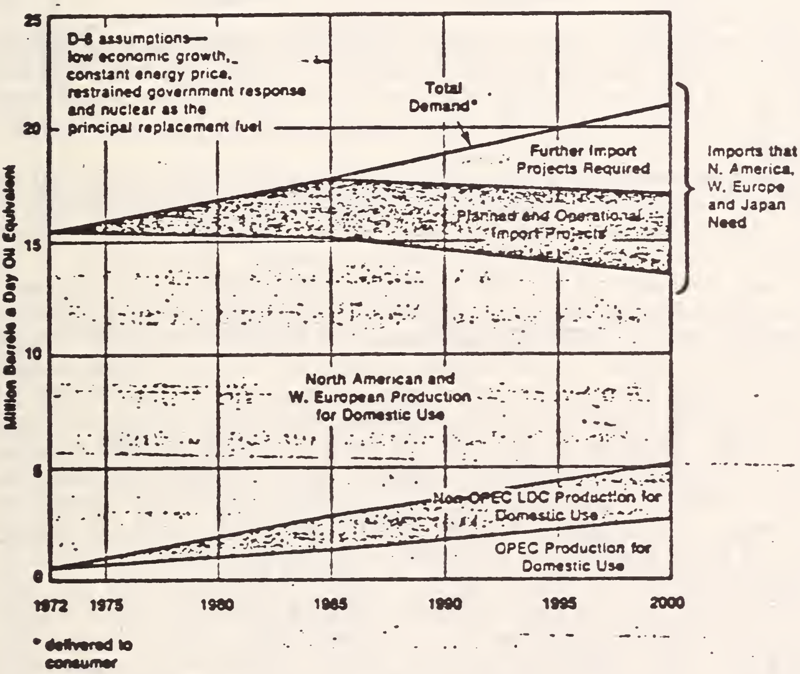


TABLE 2.—DOMESTIC SUPPLY, DEMAND, AND IMPORT REQUIREMENTS FOR NORTH AMERICA, WESTERN EUROPE AND JAPAN: 1985 AND 2000 (IN MBDOE)

	1985			2000		
	Domestic supply	Domestic demand	Import requirements	Domestic supply	Domestic demand	Import requirements
Case C–1:						
North America	10.3	11.3	1.0	8.0	10.8	2.8
Western Europe	3.5	5.0	1.5	2.0	6.1	4.1
Japan	.1	.9	.8	.1	1.6	1.5
Total	13.9	17.2	3.3	10.1	18.5	8.4
Case D–8:						
North America	8.7	9.6	.9	6.2	9.6	3.4
Western Europe	3.4	4.8	1.4	1.9	4.6	2.7
Japan	.1	.9	.8	.1	1.6	1.5
Total	12.2	15.3	3.1	8.2	15.8	7.6

FIGURE 5.—Natural gas supply and demand in WOCA: (case D–8)



Coal

Coal could be a major source of energy "gap-filler" for many countries. The problem is not related to the reserves and resource base, but to the willingness of countries to utilize coal in larger quantities within the next 25 years. The switch to cleaner fuels has left coal primarily with little more than power stations—compete with nuclear—and the steel industry as major clients. Coal can be used increasingly as a boiler fuel in industry, it can be gasified and liquefied, but at high cost and long leadtimes.

The WAES report shows that with the given assumptions about price—C1-steady increases in energy prices to reach 50 percent above current levels in real terms—economic policy—high growth—and Government policy—vigorous—coal production in the free world could increase to 3.2 billion metric tons a year by 2000 with 1.8 billion tons in North America. Constraints are: Institutional, environmental, capital, transportation, manpower, equipment.

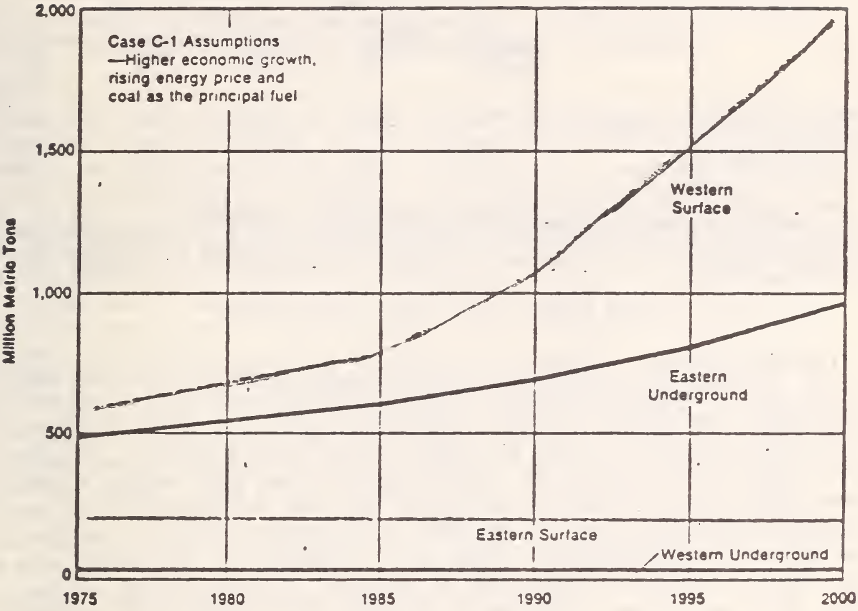
WAES shows that with coal, as with oil, there is a major conflict between desire and reality; but the conflict produces opposite effects. National preference for oil produces a prospective shortage. National distaste for coal produces a potential surplus. WAES projections of desired coal demand show that total coal use will be well below the level that energy-consuming countries would have to reach to avoid an overall energy supply gap. Large increases in coal demand require action to encourage its use and prevent excessive air pollution. Distribution systems must be built, new coal-fired equipment designed and installed, and techniques for controlling air pollution substantially improved. Coal's price in the market after providing for the cost of new transportation, coal handling, and pollution control facilities-must be sufficiently below that of competing fuels to encourage its use.

Coal gasification and possibly liquefaction may be a long-term answer to the coal-use problem because it avoids the conversion of existing oil and gas distribution and consuming systems and may simplify pollution control by concentrating coal use at a small number of sites.

Today, six countries produce 75 percent of the world's coal, that is the United States, U.S.S.R., China, United Kingdom, West Germany, and Poland. In the developing world, India is the only large producer. Twenty percent or less of total primary energy consumption in the free world consists of coal. In millions of barrels/day oil equivalent, the major industrial regions in the free world consumed the following volumes of coal in 1974: United States, 6.4 MDBOE; OECD Europe, 4.7 MBDOE; Japan, 1.1 MBDOE; rest of the free world, 3.0 MBDOE.

The United States has the largest coal reserves in the free world, and the WAES reports wonder whether the United States will produce large quantities of coal for the export market. WAES suggests that it would make economic sense to do so (higher employment, foreign exchange, and so forth), and it would also make sense from the foreign policy point of view. Exporting coal to meet the energy needs of allies and reduce dependence on Middle East oil would be consistent with U.S. foreign policy goals. The report asks correctly whether the U.S. would be willing to accept the environmental consequences and the depletion of a nonrenewable resource to provide energy for other countries? Such an export policy would require firm long-term contracts, environmentally acceptable mining and transportation techniques, and port facilities that can handle additional large volumes of coal.

Figure 6.—U.S. Coal Production Capacity (Case C–1)



To meet the coal challenge head on in the free world, there must be guarantees that coal will be available to meet potential world demand, and potential users must be convinced that coal can be burned cleanly.

Nuclear Power

WAES did not attempt to take a position on any of the hotly debated issues related to the pros and cons of nuclear power. It merely tried to show the scale of potential contributions to the world's primary energy needs in 1985 and the year 2000 that could come from an intensive and continuing nuclear power program.

Two scenarios were developed, a high- and a low-nuclear level. The high level assumes that nuclear power will be the principal replacement fuel for fossil fuels and the present political and technical obstacles will be quickly overcome. The lower nuclear level also assumes early resolution of obstacles which now delay nuclear growth in many parts of the world, but it is based on coal as the principal replacement fuel for oil. In many cases, the forecasts were based on national forecasts.

The maximum forecast (see table 3) would require an annual growth of future installed nuclear capacity to the year 2000 of 14 percent per year for 25 years; the minimum growth rate would require an annual growth rate of 11 percent. The maximum supply scenario would permit nuclear power to supply as much as 21 percent for the world's primary energy in the year 2000. This is equal to about 45 million bbl/d of oil, or as much energy as is contained in all of the free world oil production in 1975 or to the energy equivalent in 3 billion tons of coal.

TABLE 3.—SUMMARY OF WAES ESTIMATES FOR INSTALLED NUCLEAR POWER CAPACITY

		1985		2000	
	1974 (Installed capacity)	Maximum likely C	Minimum likely D	Maximum likely C–2	Minimum likely D–7
Nuclear capacity GW(e)[1]	66.9	412	291	1772	913
Percent of primary energy in WOCA (percent)	2	9	6	21	14
Oil equivalent (MBDOE)[2]	1.7	10	7	43	22

[1] GW(e) = 1,000 Megawatts (electric) = 1×10^9 watts (installed capacity) for a powerplant.

[2] We have adopted the convention of expressing nuclear electricity production in terms of the fuel input that would be required to produce the equivalent amount of electricity output from fossil-fueled power stations. The assumed generating efficiencies are 35 percent in 2000. The formula used to convert GW(e) to MBDOE, assuming 35 percent efficiency and a 60-percent load factor is:

$$\text{GW(e)} \times \frac{8760}{620{,}000} \times \frac{1}{.35} \times .6 = \text{MBDOE primary energy input}$$

The WAES study suggests that with political will and firm, prompt action on the many technical problems WAES projected, nuclear expansion is technically feasible in terms of uranium, physical facilities, and other critical resources. To achieve such nuclear growth, reactors would have to be built and uranium exploration and mining would have to be rapidly expanded, as would uranium facilities and fuel reprocessing facilities. Further research and demonstration is required before the most acceptable reprocessing methods and the most suitable sites for waste disposal can be selected. If these things are not done then our projected nuclear expansion might be delayed several years.

There are three stages in the choice of a nuclear program; (a) reactor operation which involves a single use of uranium without fuel processing, (b) the processing of used fuel to extract and recycle plutonium and uranium, and (c) operation of fast breeder reactors. (The United States is committed to the first step only; much of OECD Europe and Japan are committed to all three stages).

Beyond 2000 problems grow more serious. WAES high nuclear expansion can be maintained only if fast breeder reactors become commercial around 1990–2000. At the same time, very large additional reserves of uranium must be found and developed. It seems unlikely that breeder reactors will contribute more than 5 percent of total energy supply by the year 2000.

The WAES study concludes that uncertainties surrounding nuclear power projections are greater than for any other fuel. Extended delays on nuclear programs in various countries could hold nuclear power to the levels projected for 1985, which are based on commitments and construction already underway in most cases. On the other hand, the awareness of the growing shortfall in world oil production might lead to a new public reappraisal of the risks and benefits of nuclear power and a decision to accept the risk.

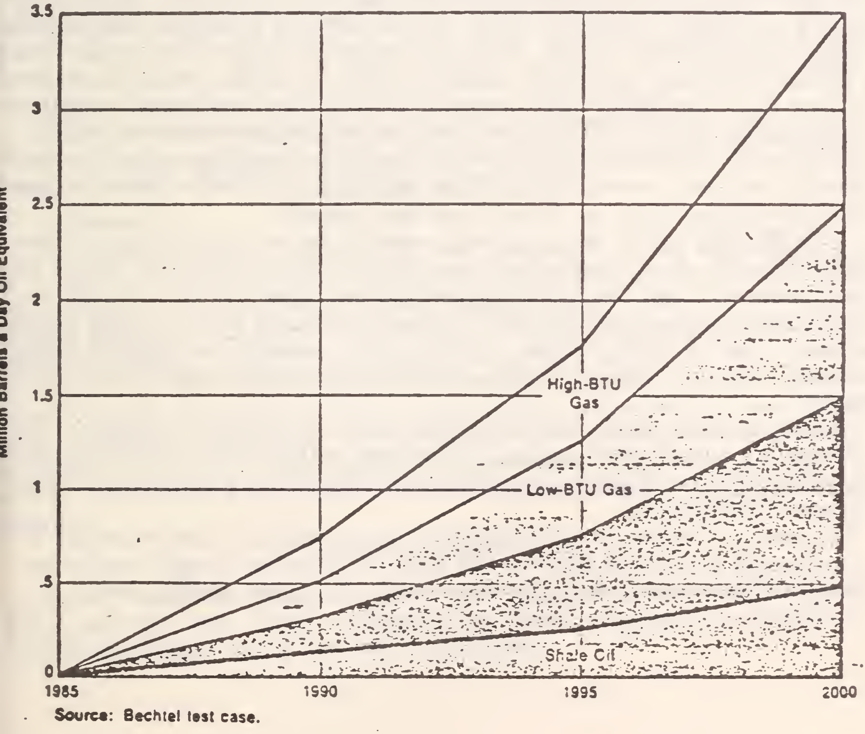
Hydropower

Much of the potential expansion of hydropower is in the developing countries where only an estimated 4 percent of the potential sites have been developed. However, growth is somewhat constrained by the location of potential sites and by long leadtimes involved with construction. Total free world hydropower production is projected to increase from 6 MBDOE in 1972 to 12 MBDOE in the year 2000 (of which a MBDOE in 1972 and 4.5 MBDOE in 2000 are for developing countries). If developed countries were to transfer some of their energy intensive industries (like aluminium) to developing countries with hydropower potential, this estimate could be increased.

Synfuels

Oil and gas from coal: The WAES study indicated potential for the production of synfuels from coal to the year 2000 within the WAES scenario, assumptions. Significant development is projected only in the high growth/high-price scenario. The maximum contribution of synfuels from coal is estimated at two MBDOE by the year 2000, with two-thirds of the gas and all of the synthetic oil produced in North America. The American development is expected to be based on conventional technology while in Europe some high-temperature nuclear reactors may be used to gasify coal. The global quantities of synthetic products would require about 600 million metric tons of coal per year. If favorable decisions were taken on coal gasification and/or liquefaction in 1977, some production would result in 1985, and significant production levels could be reached by the year 2000. Synthetic gas is estimated at cost at least $17.25 per barrel oil equivalent (the energy price in the WAES high price scenarios for 2000). Government assistance is needed according to WAES. WAES projected that for a U.S. production of 3 MBDOE of synfuels from coal and 0.5 MBDOE from shale by the year 2000, some $90 billion would be needed over a 20-year period from 1981–2000.

FIGURE 7.—Synthetic Fuel Test Case Profile



Source: Bechtel test case.

Other fossil fuels

Current production of heavy oil, oil from tar sands and from shale is less than 0.2 million bbl/d. In the WAES rising energy price scenarios, production from these sources will rise to three MBDOE by the end of the century. The resource base of shale, tar sands and heavy crude is vast, but serious social, financial, technical, and environmental problems must be solved, WAES projects Canadian oil production from tar sands at 0.8 MBDOE by the year 2000. More vigorous technical and financial action could increase production from Canadian tar sands beyond the projected level.

Shale oil production, mainly from the United States is projected at a maximum of 2 million bbl/d in the year 2000.

Geothermal

Total installed global geothermal electrical capacity was only 1,400 MWe in 1975. Energy from hot dry rocks could greatly increase geothermal resources, but the technology is still in an early stage. If research, development, and demonstration enable commercial success by 1990, electricity production from hot rocks by the year 2000 will still be in its initial stages because of the time involved in exploitation, drilling, and development of geothermal fields and the subsequent integration of the developed fields into electricity generation and distribution systems.

Solar

Solar energy has a great potential. Each year the world's solar energy income at ground level is about 5,000,000 billion barrels of oil equivalent—about 1,000 times the energy of known oil reserves, but efficient extraction of this abundant resource is difficult. The energy source is diluted, available only at intermittent intervals, subject to climatic variations, etc. In tropic latitudes sunshine is abundant and demand for space heating is small, while in more temperate latitudes winter days are short and overcast skies reduce the solar radiation reaching the collector. The need is to overcome these obstacles by finding ways to reduce the collector area required to capture this dispersed energy and by developing efficient systems to store collected solar heart for use at night or during overcast periods.

The WAES study projects solar energy to contribute one to two MBDOE for all industrialized countries in the year 2000. Most of this amount comes from solar space heating and hot water systems. Significant amounts of electricity generated from solar sources seem unlikely before 2000. Higher prices than assumed in WAES price scenarios would probably bring about larger contributions from solar energy.

Financial constraints are among the most important constraints on widespread use of solar power. It involves both the capital needed for technological development and the generally high initial cost of the systems themselves.

Despite a variety of problems and complexities, the potential of solar energy is such that after the year 2000, solar energy can be expected to plan an increasingly important role in the energy mix.

OTHER ISSUES

Energy pricing

Many people believe that the price mechanism could play a major role in producing and allocating energy efficiently and effectively. Yet it is widely recognized that price is insufficient for a variety of reasons. One of the problems is related to leadtimes and front-end capital cost. Conservation and solar energy typically have large front-end capital cost, but low operating costs. Evaluated on present discount criteria, such energy projects are disadvantaged compared to most conventional supply end use techniques. WAES suggests the possibility of some form of subsidy to take account of full costs and benefits. There may be need for international agreement on this, since individual nations may jeopardize their competitive position if they act alone.

Time is of the essence. The WAES study indicates that the adjustment process in the market, even combined with reasonably vigorous Government policies, may not alone be sufficient to make the appropriate changes unless these policies take effect in a timely fashion. Policies on pricing, investment incentives, and changes in public investment would need to be implemented very soon because long leadtimes are required for the fuel substitution and evergy conservation which are needed to extend the life of the oil era.

Technological Fixes

Technological breakthroughs—more economical and energy-efficient processes for in situ production of oil from shale, oil sand, or heavy oil, an increase in the average recovery of oil from existing oil fields significantly beyond 40 percent, in situ gasification, and rapid development of low-cost solar technologies—could all influence WAES projections. But leadtimes are such that their major impact will come beyond the year 2000. WAES suggests that it is wise to classify unanticipated bonuses of this kind as just that bonuses.

Under uncertainties such as war, large energy price increases, supply interruptions, depression, high inflation rate can occur, and would have a serious effect on the WAES conclusions.

Interdependence

The WAES report makes clear that there are many opportunities to avoid the consequences of potential energy shortages if people and nations face the problems openly and together—and do so now. World economic stability is at stake. The transition away from oil must be made in order to sustain economic stability and energy systems into the 21st century. Because of its sheer size and energy requirements, the United States must take the leadership role. Runaway inflation caused by oil pricing is not in the interest of any country, but on the other hand, the developed nations must understand the need of developing countries to protect their real purchasing power.

CONCLUSION

WAES concluded that oil production will peak somewhere between 1981 and the year 2000, depending on price, resources availability, fuel substitution, and a few other variables.

1985

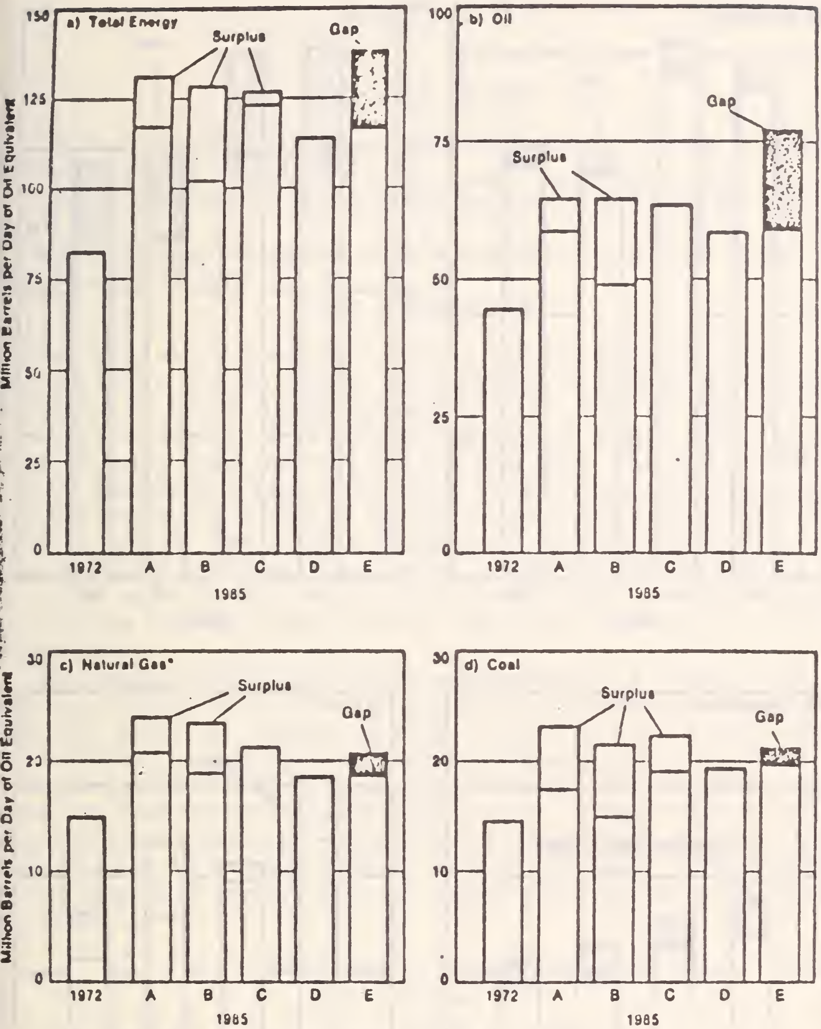
Only if the price of oil were to drop (to $7.66 in the example) significantly, certain fuels (oil in particular) might no longer be available to meet consumers' preferences for those fuels. At constant oil prices and economic growth rates of 3.4–5.2 percent per year sufficient supplies of fuels are available to meet demand. Energy preferences can be met with estimated supplies. At much higher oil prices and similar economic growth rates, there may be potential surpluses of certain fuels over consumer preferences for those fuels. No surpluses in real world. Either production will be cut to meet demand, or the price would be less than the assumed $17.25 and demand greater than at $17.25.

Figures 8 and 9 illustrate the results of the WAES supply-demand integrations in the various scenarios A–E. The figures show the primary energy demand of a preferred fuel mix resulting from the sum of national unconstrained demands. The potential supply in each case is the energy equivalent of the maximum potential supplies of all fuels. Differences between demand and supply are shortages or surpluses of total energy when preferences are compared with potentials.

2000

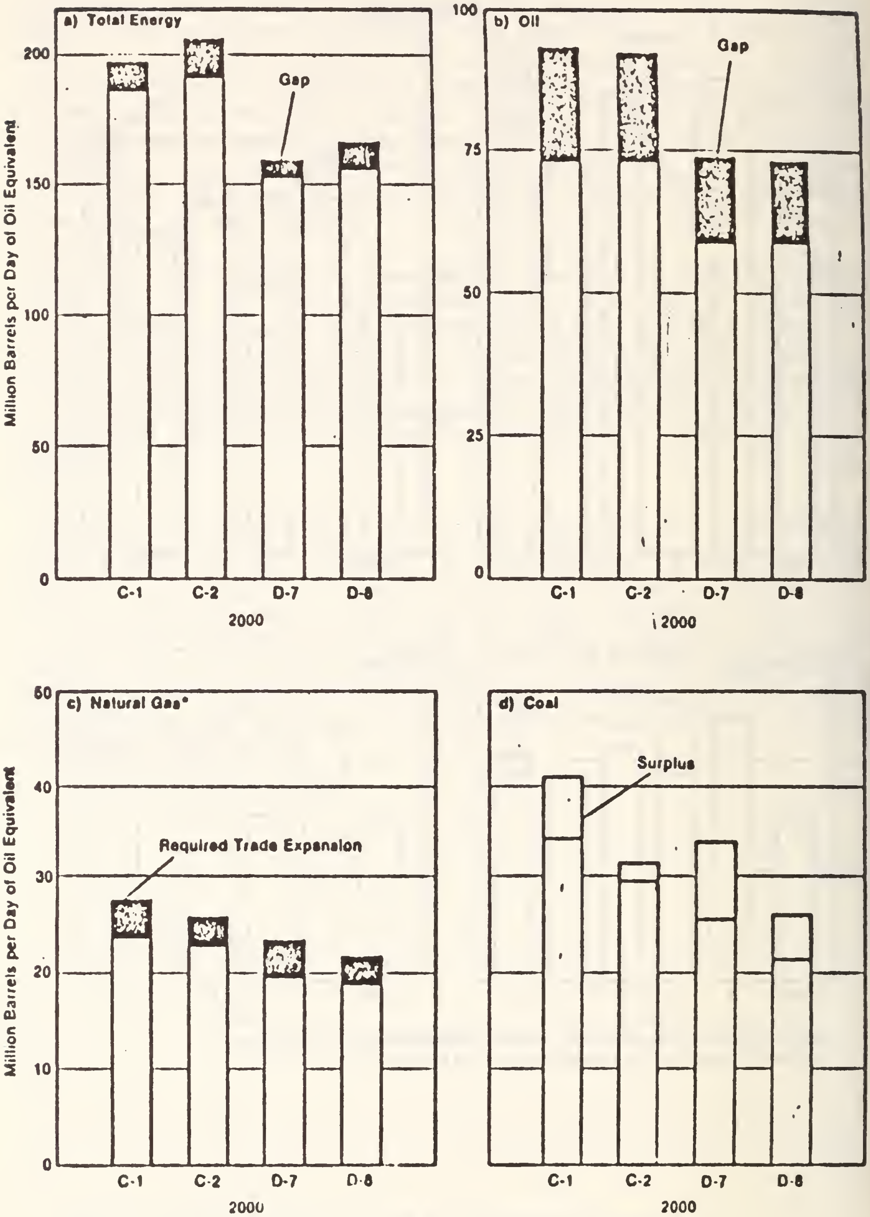
Figures 8 and 9 show the same for the year 2000, but here we find that in nearly all of the cases total desired energy demand exceeds expected supplies. This is the case even with the most efficient mix of fuels; with "preferred" mixes the discrepancy is larger. Figures 8 and 9 are not a forecast but a call for action. Because of the long leadtimes involved, action must start now, and WAES suggests that potential gaps can be filled by substituting scarcest fuels with more plentiful energy sources (coal for oil, for example) and by a large synfuel program.

FIGURE 8.—Supply and Demand, WOCA, 1985



* Natural gas supply figures are *net* production; gross production figures would be slightly higher due to processing losses in gas transport.

Figure 9.—Supply and Demand, WOCA, 2000



* Natural gas desired demands can be met by operational and planned trade plus expansion in trade projects, shown here

The CIA Report

(Central Intelligence Agency, "The International Energy Situation: Outlook to 1985," April 1977.)

(Central Intelligence Agency, "Prospects for Soviet Oil Production," April 1977.)

The CIA report examined world demand and supply of energy for the period until 1985.

KEY ASSUMPTIONS

The CIA study assumes economic growth rates averaging 4–5 percent in the United States, 3–3.5 percent in OECD Europe, and 6 percent in Japan, for the period 1977–85. The growth rate for Canada is consistent with that of the United States, reflecting the close economic links between the two countries. The slow growth in OECD Europe is related to lingering balance-of-payments problems and the continuing effects of the sharp rise in the price of oil in the 1973–74 period. The CIA projections of economic growth in the United States are lower than similar projections by the OECD for the same period (see p. 1a), but CIA projections for OECD Europe and for the 1980–85 period also for Japan are lower than the OECD projections.

The classical energy/GNP relationship based on a 4-year weighted moving average of GNP was adjusted for projected conservation measures which are already in place. Admitting that it has proved to be difficult to separate recent achievements in energy conservation from the portion of the drop in energy demand resulting from recession, the CIA analysis projects that energy savings relative to the baseline forecast will range from 10 to 15 percent in the United States and from 5 to 10 percent in OECD Europe and Japan. CIA estimates of the impact of conservation are higher than similar estimates by the OECD.

TABLE 1.—ECONOMIC GROWTH RATES—MAJOR DEVELOPED COUNTRIES

[In percent]

	Actual 1976	Projected				
		1977	1978	1979	1980	1985–85
United States	6.1	5.0	5.0	4.5	4.5	4.0
OECD Europe	4.1	3.0	3.0	3.0	3.0	3.5
Japan	6.0	6.5	6.0	6.0	6.0	6.0
Canada	4.8	4.0	4.0	4.5	4.5	4.5

TABLE 2.—ENERGY DEMAND PROJECTIONS (OECD COUNTRIES)

[Millions of barrels per day oil equivalent]

	1976	1977	1978	1979	1980	1985
Total:						
1960–73 trend	86.0	90.7	95.8	101.1	106.9	142.0
Adjusted for reduced growth	76.9	80.1	83.5	87.1	90.7	111.1
Adjusted for conservation	72.8	75.7–76.2	78.1–78.9	80.8–81.8	83.5–84.9	99.3–102.1
United States:						
1960–73 trend	42.5	44.3	46.2	48.2	50.3	61.9
Adjusted for reduced growth	38.6	40.3	42.1	44.0	45.8	55.2
Adjusted for conservation	37.2	38.5–38.9	39.6–40.3	40.7–41.6	42.0–43.1	48.2–50.4
OECD Europe:						
1960–73 trend	28.8	30.3	31.9	33.6	35.4	46.0
Adjusted for reduced growth	26.0	26.8	27.6	28.5	29.4	35.1
Adjusted for conservation	24.0	25.0–25.3	25.6–26.0	26.3–26.9	27.0–27.8	31.8–33.2
Japan:						
1960–73 trend	9.7	10.8	12.0	13.3	14.8	25.3
Adjusted for reduced growth	7.7	8.2	8.7	9.3	9.9	13.5
Adjusted for conservation	7.2	7.5–7.6	7.9–8.1	8.5–8.7	9.0–9.3	12.1–12.7
Canada:						
1960–73 trend	3.0	5.3	5.7	6.0	6.4	8.8
Adjusted for reduced growth	4.6	4.8	5.1	5.3	5.6	7.3
Adjusted for conservation	4.4	4.5–4.6	4.7–4.8	4.9–5.0	5.0–5.2	6.3–6.7

ENERGY DEMAND

On the basis of the above-mentioned economic forecast and projected energy savings, the CIA has calculated that total OECD energy demand will rise to about 100 million barrels per day (about 200 quads) in 1985. This is about 40 million barrels per day (or about 80 quads) lower than what it would have been had the oil crisis of 1973–74 not happened. About 30 million barrels per day (or about 60 quads) is due to slower economic growth now envisioned, the remaining 10 million barrels per day (or 20 quads) is due to price effects and conservation. In spite of projected lower economic growth and the effects of conservation, total energy consumption will increase 15 percent by 1980 and almost 40 percent by 1985 (using 1974 as a base year).

The United States accounts for 45 percent of OECD energy consumption in the CIA study. Its energy consumption is expected to reach 55.2 million barrels per day (or about 110.4 quads) by 1985, even with considerable conservation measures already being implemented (higher gasoline mileage under EPCA 1975). In addition, changes in lifestyles and changes in capital stock will be required to achieve a total reduction of energy consumption of 5–7 million barrels per day oil equivalent, It is assumed that new capital equipment will be 15 to 20 percent more energy efficient than the existing capital stock.

Western Europe has had a history of higher energy prices than the United States. Hence, while conservation is expected to bring demand down by about 3 million barrels per day below past energy growth trends, the efficiency of new capital must increase even faster than the rates during the 1963–73 period, but conservation is expected to have less of an effect on energy consumption than in OECD Europe and the United States.

ENERGY SUPPLY

Energy supply grew only 1 percent per year in the OECD countries during the period from 1970 to 1976. In the United States energy production actually fell due to sharper declines in oil and gas production.

CIA projects energy supply in the OECD region to expand 4 percent annually, reflecting sharp expansion of oil production in the North Sea and the opening of the Alaskan pipeline. Nuclear expansion will be considerable, but below earlier expectations due to environmental constraints. Total OECD energy production is projected to rise from 47.5 million barrels per day oil equivalent in 1976 (about 95 quads) to 56–57 million barrels per day oil equivalent (112–114 quads) by 1980. About one-half of the gain is contributed to North Sea and Alaskan oil production.

After 1980, energy production is projected to expand between a low of 1 percent and a high of 4 percent per year, or between 63 and 66 million barrels per day oil equivalent (126–132 quads) by 1985. The difference between the high and low estimate depends largely on the outcome of the nuclear debate. Additional delays in licensing and construction of nuclear power plants will have a significant effect on energy supplies within the OECD region. Recent events in the United States may serve as a useful example of what happened to nuclear power projection. In November 1974, when the Federal Energy Administration issued its Project Independence report, nuclear power capacity by 1985 was estimated at between 204 and 275 gigawatts. The latest nuclear power estimate by the FEA for 1985 is about 124 gigawatts. Higher cost, lower electrical energy demand, problems related to the fuel cycle, and above all opposition by antinuclear forces have contributed to the lower estimates.

TABLE 3.—DOMESTIC ENERGY PRODUCTION[1] (OECD COUNTRIES[2])

[Millions of barrels per day oil equivalent]

	1970	1976	1980	1985
Total	45.2	47.5	56.0–57.0	63.2–66.1
Oil[3]	13.3	12.2	15.2	15.9–17.2
Natural gas	13.6	14.8	15.2–15.6	15.9–16.9
Coal	13.8	14.0	16.5–17.2	18.1–19.6
Hydro/geothermal	4.2	4.6	5.4	6.5
Nuclear	.3	1.9	3.4–3.8	5.4–7.2
United States	30.8	30.2	32.1–33.0	34.7–37.1
Oil[3]	11.3	9.7	10.0	10.0–11.0
Natural gas	11.4	10.3	9.0–9.6	8.5–9.5
Coal	6.7	7.6	9.5–10.2	10.5–12.0
Hydro/geothermal	1.3	1.6	1.7	2.0
Nuclear	.1	1.0	1.6–1.8	2.5–3.8
OECD Europe	9.4	11.3	16.7–17.1	19.2–20.8
Oil[3]	.5	.9	3.7	4.0–5.0
Natural gas	1.4	3.3	4.6	5.4
Coal	5.6	4.9	5.1	5.3
Hydro/geothermal	1.7	1.6	2.1	2.4
Nuclear	.2	.6	1.2–1.6	1.8–3.0
Japan	1.7	2.0	2.7–2.8	3.9–4.2
Oil	0	0	0	.1
Natural gas	.1	.2	.5	1.0
Coal	1.2	1.2	1.5	1.8
Hydro/geothermal	.4	.4	.4	.6
Nuclear	0	.2	.3–0.4	.4–0.7
Canada	3.3	4.0	4.2–4.4	4.5–4.9
Oil[3]	1.5	1.6	1.5	1.3–1.5
Natural gas	.7	1.0	1.0–1.1	1.0–1.2
Coal	.3	.3	.4	.5
Hydro	.8	1.0	1.2	1.5
Nuclear	0	.1	.1–0.2	.1–0.3

[1] Defined as domestic production of oil and total domestic consumption of all other fuels.
[2] Excluding Australia and New Zealand.
[3] Including natural gas liquids.

Coal production estimates are also uncertain. The CIA report projects a 40–60% increase in U.S. coal production, but admits that this figure may be too high if environmental and institution constraints on coal utilization in the United States cannot be overcome. Coal accounts for as much as 70 percent of the projected rise in U.S. energy production in the CIA study.

OECD oil production is projected to grow from about 12 million bbl/d in 1976 (of which 9.7 million bbl/d U.S.) to about 16 or 17 million bbl/d by 1985 (10 to 11 million bbl/d U.S.).

Outside the OECD area, oil production in non-OPEC LDC's is estimated to increase from 3.7 million bbl/d in 1976 to between 8 and 9 million bbl/d by 1985. Oil production in Australia and New Zealand is projected to remain at about current levels of 0.5 million bbl/d. Outside OPEC, Mexico and Egypt are projected to make the largests gains in oil production.

THE COMMUNIST WORLD

The area of greatest controversy in the CIA study is related to oil supply projections for the Sovier Union. The CIA projects that Soviet oil production will peak not later than 1980 at between 11 and 12 million bbl/d. The decline is projected to be sharp when it comes.[1]

The effects of the decline in Soviet oil production during the late 1970's or early 1980's are serious for both the Communist world and the West. The decline, according to the CIA, will come so fast that substitution of more plentiful energy resources will not be able to make up for the losses in oil production. Exports to both the East and the West will have to be reduced, and net imports of the Soviet bloc of OPEC oil will rise to between 3.5 and 4.5 million barrels per day by 1985.

Chinese oil production is likely to keep pace for domestic oil consumption, but exports are projected to be no more than 500.000 barrels per day in 1980, falling to negligible levels by 1985.

DEMAND FOR OPEC OIL

OPEC oil production recovered in 1976 from the 1974–1976 decline in world oil demand. The decline was caused by the severe recession of 1974–1976, from which much of the industrial world has not yet recovered. The quadrupling of the price of oil was an important contributor to the recession. High demand for OPEC oil, in particular from the United States, which is leading the industrial world out of the most severe postwar recession, accounts for most of the expanded OPEC oil exports. The CIA report projects OPEC oil production to reach 32 million barrels per day in 1977 and expects little change in OPEC output during 1978 and 1979, when additional demand for oil by the industrial nations will be satisfied from North Sea and North Slope production. The CIA estimates OPEC production to jump another 2 million barrels per day in 1980, beginning a strong upward trend. Alaskan output will have stabilized, and growth in North Sea production will be slowing. The CIA also expects the Soviet Union to cease being a net oil exporter to the West by 1980.

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[1] For more detailed analysis of the Soviet oil situation, see p. 302.

Total demand for OPEC oil is projected at 34 million bbl/d in 1980. With the exception of Saudi Arabia, OPEC producers are expected to produce at or near capacity, and the Saudis, as a residual supplier, can produce within its preferred range. If it wants to, Saudi Arabia can use its excess capacity to encourage price moderation.

After 1980, demand for OPEC oil is projected to rise sharply, reaching an output of between 47 and 51 million bbl/d by 1985. The CIA projects U.S. imports to rise to 10.5 million bbl/d in 1980, and 12–15 million bbl/d in 1985. OCED Europe would import between 10 and 11 million bbl/d in 1980 and between 11 and 14 million bbl/d by 1985. Japan, with few energy options to choose from, is projected to increase oil imports to 8.5 to 9.0 million bbl/d by 1985. Developing, non-OPEC countries as a bloc will reduce their dependence on OPEC oil, but much of the projected higher supply of non-OPEC oil from LDC's is likely to come from Mexico and Egypt.

PRODUCTIVE CAPACITY

CIA estimates that the productive capacity of OPEC countries other than Saudi Arabia will increase little, if at all, between 1980 and 1985. From close to 27 million bbl/d today, productive capacity of OPEC countries other than Saudi Arabia may increase to 28 million bbl/d in 1980 and no more than 29 million bbl/d by 1985.

Saudi Arabia is considered the "swing country" on which the rest of the world may have to rely for available oil supplies. The CIA report estimates demand for Saudi oil at 7 million bbl/d in 1980, 12 million bbl/d in 1982, 13–16 million bbl/d in 1983, and 19–23 million bbl/d by 1985. CIA questions—and in our opinion correctly so—if the Saudis willingness to produce this much oil at any time. Production of 20 million bbl/d by 1985 could not be sustained for more than a decade, according to the CIA study.

TABLE 4.—OIL IMPORT PROJECTIONS FOR NON-OPEC FREE WORLD COUNTRIES (EXCLUDING OECD COUNTRIES)

[Millions of barrels per day]

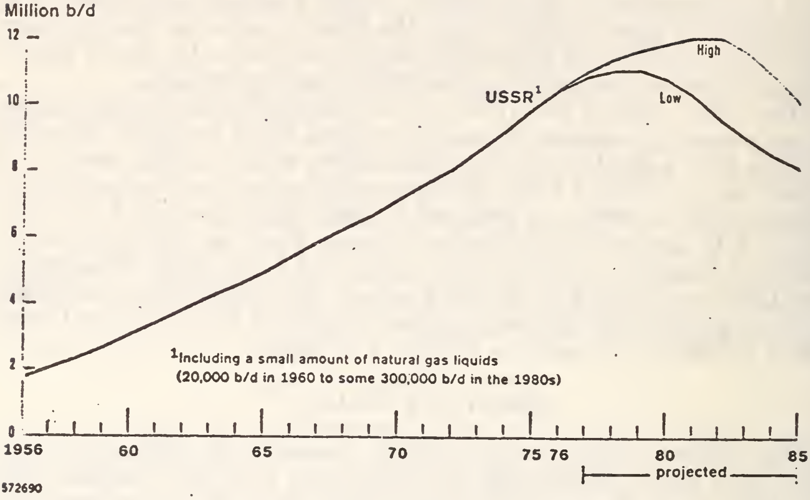
	1976	1977	1978	1979	1980	1985
Oil demand	7.9	8.3	8.8	9.1	10.0	13.9
Australia/New Zealand	.7	.7	.8	.8	.9	1.2
Other developed countries [1]	.5	.5	.5	.5	.6	.7
Non-OPEC LDC's	6.7	7.1	7.5	7.8	8.5	12.0
Oil supply [2]	4.2	4.6	5.1	5.8	6.6	8.4–9.4
Australia New Zealand	.5	.5	.5	.5	.5	.4
Non-OPEC LDC's	3.7	4.1	4.6	5.3	6.1	8.0–9.0
Oil imports	3.7	3.7	3.7	3.3	3.4	4.5–5.5
Australia/New Zealand	.2	.2	.3	.3	.4	.8
Other developed countries [1]	.5	.5	.5	.5	.6	.7
Non-OPEC LDC's	3.0	3.0	2.9	2.5	2.4	3.0–4.0

[1] Israel and South Africa.

[2] Including natural gas liquids.

Soviet Crude Oil Production

Table 5



[1] Including a small amount of natural gas liquids (20,000 b/d in 1960 to some 300,000 b/d in the 1980s)

SOVIET OIL PRODUCTION AND IMPORTS

Acceptance of the CIA scenario described here depends to a large extent on one's outlook of Soviet energy policy. The CIA report indicates that the Soviet bloc may be importing 3.5 to 4.5 million bbl/d by 1985. If one assumes—as many competent analysts do—that the U.S.S.R. will not be net importer of important volumes of oil by the middle 1980's, the need for Saudi oil as projected in the CIA report, could be reduced by 3.5 to 4.5 million bbl/d. We are the first to admit that this would still leave the Saudis with the difficult decision whether to produce as much as 15.5 to 18.6 million bbl/d in 1985 (assuming the reminder of the CIA demand/supply analysis is left intact).

The CIA issued a special report entitled: "Prospects for Soviet Oil Production" in April 1977, or about the same time it released the "International Energy Situation; Outlook to 1985." The main conclusions of the former study are: (1) For a number of resources and management related problems, Soviet oil production is likely to peak during the next few years. The Soviets for years have emphasized development drilling over exploration, with the result that new oil discoveries are failing to keep pace with output growth. Moreover, in their eagerness to maximize production from existing fields, they have used techniques which indeed had the desired short-term effect, but which are also expected to lead to less ultimate recovery of oil-in-place from fields where such techniques have been applied. (2) The Soviet Union has not found sufficient new oil fields to make up for projected losses in the older fields in European Russia. About 20 percent of current oil production is from one giant field in Siberia, and no new giant fields have been found in recent years.

The Soviet problem in meeting oil production targets has grown progressively worse. During the 1961–65 plan, only 1.3 million bbl/d of capacity lost in older fields had to be replaced. In 1974–75, 5.1

million bbl/d of replacement capacity was required because of rapid depletion. Or, as the CIA study indicates, about 70 percent of the 1970 oil production capacity had to be replaced by the end of 1975. The CIA estimates that of the target figure of 10.6 to 10.8 million bbl/d for the 1976–80 plan, 7.8 million bbl/d (or about 80 percent of the capacity on line in 1975) is to offset depletion. The CIA suggests that it might even be higher than 7.8 million bbl/d.

CIA estimates of Soviet reserves are rather low at about 30–35 billion barrels. Some Western sources have published reserve data almost twice that figure for the U.S.S.R. The CIA adds: "There is no doubt that Russia proved reserves have been falling in recent years, and there is very little chance that enough oil will be discovered during the next few years to appreciably improve the reserve-to-production ration." The CIA recognizes, however, that potential oil resources in the U.S.S.R. are huge, but development of those resources is at least a decade away.

On the basis of current reserves and the problems in the older producing areas west of the Urals, the CIA projects that the Soviet plan, which calls for doubling of oil production east of the Urals, and maintaining production west of the Urals, cannot be met. All growth in output will come from west Siberia, and even there no giant fields comparable to the Samotlor Field (which produces 20 percent of total output) have been found. Moreover, the Soviets do not have the drilling capability to pursue adequate development and exploration programs simultaneously. Hence, major efforts to increase development drilling to meet the current plan, could result in slower oil exploration programs. This in turn would effect future production.

The CIA report projects Soviet oil production to level off at between 11 and 12 million bbl/d not later than the early 1980's. The initial falloff, when it comes, will almost certainly be sharp, according to the CIA. Thereafter, output may continue to fall sharply, level off, or perhaps even increase as new fields are brought into production in frontier areas such as the Caspian Sea, the Mangyshlak Peninsula, or the Pechora region west of the Urals. There is no doubt that new large fields will eventually be found, but the big question is how soon. The CIA doubts that new discoveries will come on stream rapidly enough to do more than temporarily arrest the rapid slide in Soviet output. Leadtimes could be shortened with large infusion of Western technology and capital. The United States and its allies will have to decide whether such investments will benefit the West in the end.

The CIA report does not emphasize the energy conservation potential, nor does it adequately cover the potential for interfuel substitution. Soviet natural gas and coal reserves are known to be huge. How soon and at what costs can the Soviets replace potentially declining oil output with natural gas, coal and other energy sources?

The effects of potential shortfalls in Soviet oil production will also be discussed in other parts of this analysis (see CRS study).

In its entirety, the CIA report is probably the most pessimistic of recent international energy studies. The CIA report suggests the potential for price jumps soon after 1980, when the world oil supply/demand equation would require large increases in Saudi oil production. For economic and political reasons the Saudis may decide not to expand output beyond a certain level, causing prices to rise.

Organization for Economic Cooperation and Development, World Energy Outlook, Paris, 1977

This is the second major energy study published by the OECD. The first study, entitled "Energy Prospects to 1985" was published at the beginning of 1975. The effects of the 1973–74 quadrupling of the price of oil are noticeable in the 1977 study in several areas. Economic growth rates for the OECD area were projected at 5.1 percent annually for the 1971–85 period; the new study estimates OECD economic growth rates at 4.1 percent annually. The higher energy prices along with other factors are projected to keep economic growth rates down.

GDP GROWTH

In OECD Europe, GDP growth rates are projected to grow at an annual average rate of 3.6 percent between 1974 and 1980, and at 4.1 percent between 1980 and 1985. The United States is projected to grow at 4.4 percent a year between 1974 and 1980, and at 3.5 percent between 1980 and 1985. Comparative growth figures for Japan are 6.0 percent for 1974–80, and 6.6 percent for the 1980–85 period. Differences in economic growth assumptions have a major impact on energy consumption.

TABLE 1.—GDP GROWTH RATES FOR THE REFERENCE AND ACCELERATED POLICY CASES

[Percent per year]

	1974–80	1980–85
Belgium	3.3	4.6
Denmark	2.8	4.0
France	4.5	5.5
Germany	3.5	3.5
Ireland	3.0	4.0
Italy	3.0	4.0
Luxembourg	3.0	4.6
Netherlands	3.0	3.0
United Kingdom	2.5	3.0
Total, EEC	3.4	4.0
Austria	3.0	3.4
Norway	6.8	3.7
Spain	4.3	5.0
Sweden	3.0	3.2
Switzerland	1.8	2.3
Turkey	7.8	7.8
Finland Greece Iceland Portugal	4.7	4.4
Total, OECD Europe	3.6	4.1
United States	4.4	3.5
Canada	4.8	4.0
Japan	6.0	6.6
Australia	3.8	4.5
New Zealand	3.5	3.3
Total, OECD	4.3	4.1

TABLE 2.—ENERGY PRODUCTION, CONSUMPTION AND IMPORTS IN THE UNITED STATES IN 1974, 1980, AND 1985

	1974	1980	1985 Reference case	1985 Accelerated policy case
Oil (million barrels per day):				
Production	10.4	10.8	11.6	14.1
Consumption [1]	15.9	19.8	21.0	18.4
Net imports	5.8	9.3	9.7	4.3
Natural gas (trillion cubic feet per year):				
Production	20.9	17.5	19.2	22.2
Consumption	21.7	18.8	20.9	23.9
Net Imports	.9	1.3	1.7	1.7
Coal (million short tons per year):				
Production	620.0	799.0	1,039.3	1,039.3
Consumption	570.0	719.0	961.3	930.3
Net Imports	−60.6	−80.0	−78.0	−109.0
Nuclear power (terawatt-hours per year)	120.6	415.0	927.0	927.0
Hydro and geothermal power (terawatt-hours per year)	309.9	334.0	356.0	356.0
Total electricity (terawatt-hours per year)	2,093.1	2,467.0	3,265.0	3,217.7
Total energy (requirements (Mtoe per year)	1,713.7	1,990.0	2,360.1	2,286.4

[1] Marine bunkers are included in imports, but are excluded from consumption. The quantities given above in original units are translated into Mtoe in the energy balance for United States in annex table A-3 and A-13.

ENERGY DEMAND

The OECD projects slower energy demand in the OECD as a whole than in the past. Production from indigenous supplies will increase more quickly than in the past but more slowly than demand. Hence imports will continue to rise, but more slowly than in the past. In the period from 1960–73, energy consumption in the OECD grew at an annual average of 5.1 percent; the OECD projects annual energy consumption in the period from 1975–85 to be more than 3.6 percent. This is in part due to the lower economic growth forecast (down from 4.6 percent a year for 1960–73, to 4.2 percent annually for 1975–85), and also due to changes in the energy/GDP ration (from 0.99 in 1960–73 to 0.84 for 1975–85) caused by higher energy prices and direct Government action in the area of conservation.

Oil consumption is projected to decline even more rapidly than total energy consumption in the OECD. Between 1960 and 1974, oil consumption grew at 6.7 percent a year. The OECD report projects oil consumption to decline to 3.1 percent annually between 1975–85, and its share in total energy requirements is projected to decline from 51 percent in 1974 to 49 percent in 1985. Like oil, natural gas consumption in the OECD is projected to grow, but its share in total energy consumption would decline from 20 percent in 1974 to 17 percent in 1985. Coal consumption showed no net growth between 1960 and 1974, but is expected to grow at 2.7 percent a year to 1985. Coal's share in total OECD energy requirements is projected to decline from 20 percent in 1974 to 18 percent in 1985. Most of the actual expansion will be taking place in the United States. The share of nuclear power is estimated to increase from 2 percent in 1974 to 9 percent in 1985.

ENERGY PRODUCTION

In the 15 years prior to the Arab oil embargo, energy production in the OECD countries expanded only 2.8 percent a year on the average—only 1.2 percent annually from 1969–74. Availability of cheap Middle East oil created a disincentive for the production of energy from domestic sources. The quadrupling of the price of oil and the shock effect of the Arab oil embargo has created new incentives for energy production in the OECD countries. The OECD study projects energy supply to increase by 3.5 percent per year from 1974–85. Success, however, depends to a large extent on nuclear power programs. Nuclear capacity is projected to almost quadruple in the OECD between 1974 and 1980, and increase alsmost eight times over 1974 capacity by 1985.

Oil imports in the OECD countries, which increased 9.9 percent a year between 1960 and 1973, is projected to increase at the same pace as domestic energy production, at 3.5 percent annually. In volume, oil imports in the OECD countries would expand from 23.4 million barrels per day in 1975 to 30 million barrels per day in 1980 and 35 million barrels per day by 1985. Hence, the decline in oil imports during the 1974–75 period which reached a trough in 1975, was expected to be reversed, returning to the 1973 peak oil import level before 1980. Thereafter, oil imports are projected to continue to rise. The base case in the 1977 OECD study contrasts with the more optimistic 1975 energy report. The latter was much more optimistic about the ability of Europe and the United States to limit vulnerability to oil import interruptions by moving closer toward self-sufficiency. In both studies the world price of oil in the base case was the same—about $11.50 per barrel for Arabian 34° crude.

It should be pointed out that in addition to the base case, the OECD study also developed alternative scenarios, that is, an accelerated case assuming a vigourous energy policy; a slow economic growth rate combined with existing energy policies; and, a fast economic growth scenario with existing energy policies. Depending on the assumption, energy consumption will be higher or lower in these projections. The effects of the different scenarios on energy consumption are very significant. The difference between an average 3.7 percent and a 4.7 percent annual economic growth rate translates into additional oil imports of 6.9 million barrels per day by 1985, and the difference between each one of these two cases and the base case of 4.1 percent is about 5 million barrels per day of oil equivalent.

The OECD study concludes that unless the member states implement a more aggressive conservation and supply policy, oil imports are likely to expand from 19 percent of total energy consumption in 1960 to 34 percent by 1985. Like many other studies, the OECD treats oil imports as a residual after subtracting supplies of all forms of energy and nonoil imports from total energy consumption. The OECD analysis concede that this is the actual situation. Shortfalls in production of indigenous fuels or increases in energy demand put pressures everwhere on the energy system, but the most expansible point is oil imports because oil production in the main producing countries is physically the most readily expansible source and also the lowest cost. The OECD study concludes that to the extent that oil imports are a residual, the energy source of the last resort, errors in any of the other variables in the productions affect oil imports, and small percentage changes in large variable such as total energy requirements; are to large percentage changes in oil imports.

REGIONAL ENERGY DEMAND AND SUPPLY: UNITED STATES

The United States is the principal energy consuming nation in the OECD. It has the largest potential for energy conservation, and if compared with OECD Europe as a whole the largest potential for energy self-sufficiency. The OECD study estimates that the United States alone could reduce oil imports to the equivalent of 55 percent of the savings achievable by all countries of the OECD. While the authors of the OECD study consulted extensively the 1976 national energy outlook of the FEA, they made adjustments in certain areas of demand and supply.

GDP GROWTH

The OECD study assumes GDP growth rates in the United States of 4.4 percent annually between 1974 and 1980, and 3.5 percent annually for the next 5 years to 1985.

OIL PRICE

On domestic oil prices, the OECD study assumes in the base case that the domestic composite price will increase by 10 percent a year, and that by June 1979 mandatory controls will lapse. For both 1980 and 1985, oil prices are assumed to be at international levels, or $13 per barrel. If oil is not decontrolled by 1979, production could be 500,000 darrels per day below base case projections.

ENERGY DEMAND

In view of the fact that OECD estimates slightly higher economic growth rates in the United States than the national energy outlook, total, energy demand by 1985 is estimated at 2,360.1 Mtoe—million tons of oil equivalent—or about 95.6 Quads. (Includes some savings caused by conservation measures already passed in Congress, or brought about by higher prices.)

NATURAL GAS PRICING

OECD assumes continued price controls on interstate natural gas. The reference case assumes that wellhead price of interstate gas will be raised to $1.50 per thousand cubic feet—mcf—or $0.80 below the NEO estimate of the market-clearing or decontrolled price. Uncertainties remain about gas held off the market for higher prices, about remaining resources, lead times to develop those resources, and price elasticity of supply. The OECD base case of 19.2 trillion cubic feet production by 1985 assumes a price of $1.50 per thousand cubic feet, and 22.2 trillion cubic feet under decontrol of natural gas.

Recognizing the uncertainties surrounding decontrol and price elasticity of supply, the OECD report suggests that under natural gas decontrol the NEO projection of 23.4 trillion cubic feet of natural gas production by 1985 might very well be achievable.

ENHANCED RECOVERY OF OIL AND NATURAL GAS

Advanced recovery techniques could eventually result in reserve additions of 40 billion barrels of oil and 250 trillion cubic feet of natural gas in the United States. Costs are likely to be well in excess of OECD's assumed constant price of imported oil, and lead times of new techniques will require upward of 10 years. Thus, the OECD study suggests that even an accelerated development plan would produce no more than 900,000 barrels per day of additional oil and associated natural gas through more extensive use of enhanced recovery techniques before 1985.

ALASKAN OIL

Long lead times for the development of Cook Inlet and Gulf of Alaska oil, and the prospects that no additional pipeline capacity in Alaska will materialize beyond looping of the present Alaska line to 2.5 million barrels per day, limits Alaskan oil production pretty much to a maximum of 2.5 million barrels per day in 1985.

OCS AND NPR NO. 4

The OECD follows the national energy outlook of 1976 as far as Outer Continental Shelf leasing schedules are concerned, with the exception that the onset of Atlantic Outer Continental Shelf production is deferred to after 1985 in the base case—1985 in the accelerated case.

SYNGAS AND LNG

In neither the reference nor the accelerated case is there any allowance for production of SNG from coal or gas from tight formations, because both processes are basically uneconomic compared with imported oil, and also because needed capital may be diverted from development of conventional natural gas once gas prices are deregulated—assumed in accelerated case. LNG imports are limited to about 0.7 trillion cubic feet in the base case and the accelerated case.

ELECTRICAL DEMAND SECTOR

Electricity demand is projected to grow at 5½ percent annually. OECD recognizes uncertainty of demand for electricity and uncertainty about the choice of fuel of generation. High financing costs of nuclear powerplants, long leadtimes, uncertainty as to the future cost margin per kilowatt-hour between nuclear and fossil-fuel generation, and public resistance about safety, siting, waste disposal, and thermal pollution, will affect the nuclear power industry. OECD still believes that by 1985 about 25 percent of generated electricity will be based on nuclear power. Both coal and residual fuel oil are expected by 1980 to nearly double in demand as feedstock to thermal plants, while natural gas used to generate electricity is expected to halve in the same period to 1985.

The installed capacity nuclear generation of electricity is projected at 73 gigawatts in 1980 and 152 gigawatts by 1985. Those estimates reflect the latest available count of plant orders, deferrals and reinstatements, available to the OECD early this year—1977.

Coal production is projected to rise from 651 million short tons in 1976 to 800 million tons in 1980 and 1,040 million tons in 1985. About two-thirds of domestic coal demand is from the electricity sector. The OECD study is optimistic about the coal conversion program. Environmental questions are expected to be overcome by FEA ruling to grant variances from emission standards. In view of the fact that a Bureau of Mines study indicates that some 225 million tons of coal are already being burned in violation of environmental emission standards, the OECD report suggests that granting such variances by FEA will only legalize de facto variances and therefore not represent an additional stimulus. The OECD recognized that pending strip mining legislation (signed by the President on August 3, 1977) could restrict strip mining in some areas. Federal leasing of coal lands is also listed as a constraint, because 75 percent of the low sulphur coal recoverable by surface mining is located on Federal lands. The Department of the Interior has issued a moratorium on such leases until a number of issues have been clarified. In 1974 only 3 percent of these Federal lands were developed. Finally, the OECD study lists the disrepair of railroad beds and the inadequacy of rolling stock among the more serious impediments to coal production expansion. Some of this could, however, be corrected in time.

TABLE 3.—ENERGY PRODUCTION, CONSUMPTION AND IMPORTS FOR OECD EUROPE IN 1974, 1980 AND 1985

			1985	
	1974	1980	Reference case	Accelerated Policy case
Oil (million barrels per day):				
Production	0.4	3.5	4.3	4.3
Consumption [1]	13.3	14.9	18.0	14.6
Net imports	14.1	12.4	14.7	11.2
Natural gas (billion cubic meters per year):				
Production	157.7	226.1	228.9	257.9
Consumption	174.4	258.2	311.8	341.9
Net imports	16.7	32.1	83.0	84.0
Coal (million metric tons per year):				
Production	416.6	434.0	436.0	436.0
Consumption	467.0	507.2	516.0	552.6
Net imports	51.3	73.2	80.0	116.6
Nuclear power (terawatt-hours per year	82.9	341.0	702.0	850.0
Hydro and geothermal power (terawatt-hours per year)	366.3	421.7	474.2	474.0
Total electricity (terawatt-hours per year)	1,426.3	1,895.0	2,593.0	2,528.0
Total energy requirements (Mtoe per year)	1,159.5	1,401.8	1,704.4	1,619.2

[1] Marine bunkers are included in imports, but are excluded from consumption. The quantities given above in original units are translated into (Mtoe)in the energy balance for OECD-Europe in Annex Tables A4 and A14.

TABLE 4.—ENERGY PRODUCTION, CONSUMPTION AND IMPORTS IN JAPAN IN 1974, 1980 AND 1985

			1985	
	1974	1980	Reference case	Accelerated policy case
Oil (million barrels per day):				
Production	0.01	0.03	0.07	0.07
Consumption [1]	4.8	6.4	8.2	7.1
Net imports	5.3	6.9	8.8	7.6
Natural gas (billion cubic metres per year):				
Production	2.9	4.7	9.8	9.8
Consumption	8.6	30.7	55.7	68.7
Net imports	5.7	25.9	45.9	59.0
Coal (million metric tons per year):				
Production	21.5	20.0	20.0	20.0
Consumption	86.8	106.5	118.4	118.4
Net imports	64.6	86.5	98.4	98.4
Nuclear power (terawatt-hours per year)	19.7	86.0	199.0	279.0
Hydro and geothermal power (terawatt-hours per year)	84.8	89.0	117.0	117.0
Total electricity (terawatt-hours per year)	459.0	663.0	922.0	899.0
Total energy requirements (Mtoe per year)	334.4	470.1	627.0	600.0

[1] Marine bunkers are included in imports, but are excluded from consumption. The quantities given above in original units are translated into Mtoe in the energy balance for Japan in Annex Tables A6 and A15.

REGIONAL ENERGY DEMAND AND SUPPLY: OECD EUROPE

OECD Europe is not expected to become more dependent on oil imports between 1974 and 1985. The main reasons for this are the production increases in North Sea oil and nuclear power over the forecast period.

GNP growth rates are expected to grow at 3.6 percent annually to 1980, and at 4.1 percent between 1980 and 1985. Energy growth rates are expected to decline due to higher process and conservation measures. The energy/GDP ratio is projected to change from 1.14 for the 1960–73 period, to 0.93 for 1974–85. Over and above these implied savings the OECD estimates another 5 percent of additional energy savings for OECD Europe in the accelerated scenario. Clearly, room for energy savings is much more limited in OECD Europe than in the United States, where energy prices have been traditionally low.

OIL PRODUCTION

North Sea production is projected to increase to 2.2 million barrels per day in the United Kingdom and 0.85 million barrels per day in Norway by 1980. Production by 1985 is estimated at 3.9 million barrels per day for the United Kingdom and Norway together. The actual production level will be influenced by leasing policy, and could be higher than the projected 3.9 million barrels per day. Norway, in particular, may slow down oil exploration, because it does not want to overheat the Norwegian economy from oil sales.

The OECD study indicates that a more vigorous exploration and development plan in Norway could increase production beyond the 940,000 barrels per day projected for 1985. Government policy, however, is not likely to allow speedier oil and gas development in Norway. The United States is in a different position. It is likely to continue an active exploration and development program to increase production to 3 million barrels per day by 1985. The British economy can absorb the additional income from exports with no difficulty at all.

NATURAL GAS

The Netherlands is the largest natural gas producer in OECD Europe. Production in that country is projected to grow from 84.8 billion cubic meters or about 2.9 trillion cubic feet in 1974 to 103 billion cubic meters or (3.6 TCF) in 1980. By 1985, production could fall to 92.0 billion cubic meters (3.2 TCF) or, under the accelerated scenario, grow to 111.0 billion cubic meters (3.9 TCF). Most of the Dutch gas is produced from the Slochteren field which is estimated to hold between about 55 and 76 TCF. All of OECD Europe is projected to produce 226.1 billion cubic meters (or 2.5 TCF). In 1985, production is estimated at between 228.9 billion cubic meters (8.0 TCF) and 257.9 Mtoe (9.1 TCF). In addition OECD Europe is projected to import about 80 billion cubic meters (2.8 TCF) from the U.S.S.R., Algeria, Iran, and Libya.

NUCLEAR POWER

Ever since the 1973 Arab oil embargo, European governments have focused on nuclear power as the one source of energy that could be increased rapidly enough to serve as a replacement for imported oil.

An ambitious 1974 plan to increase EEC nuclear capacity to 200 gigawatt (GWe) by 1985, was soon lowered to 160 GWe in 1975. The OECD study reduced this estimate even further to 91.4 GWe by 1985. Downward revisions in projected electricity demand and realization of numerous constraints on nuclear powerplant construction, have led to reduced projections of future nuclear power capacity. Long leadtimes for powerplant construction, high capital cost, technical problems, public anxiety over safety and environmental difficulties, waste disposal, and the fear that nuclear materials may be diverted to produce weapons, are among the many constraints on expanding nuclear power generation of electricity. OECD nuclear capacity is projected to grow to 55.5 GWe in 1980 and 114.6 GWe by 1985. An accelerated development program could add another 24.3 GWe to this. The latter would require that licensing and construction leadtimes be reduced from current levels.

COAL PRODUCTION

Total coal production in the OECD declined from 334 million tons of oil equivalent (Mtoe) in 1960 to 206 Mtoe in 1974. For the OECD as a whole, the OECD projects a slight production increase in 1980 (to 217.8 Mtoe), and much of the increase is said to take place in the United States; Spain, and Turkey. German and French coal production are projected to further decrease, but at a slow pace. Coal imports are estimated to increase from 51.3 million metric tons in 1974 to 80 million tons in 1985. The accelerated scenario adds another 26.6 million metric tons to coal imports, which would substitute oil in powerplants.

The lower production of German coal is explained by lower demand for electricity and lower projections for coking coal exports. Coal imports of electrical power generation are a substitute for residual fuel oil. Uncertainty of oil prices have to be weighed against the higher environmental costs of coal use. labor stoppages at coal mines, and security of foreign coal supplies. At current oil prices, residual fuel oil competes favorably with European steam coal in some areas.

HYDRO AND GEOTHERMAL POWER

Considerable increase in production of hydro and geothermal power is projected. Expanded power production from those sources could save as much as 500,000 bbl/d of oil imports. Larger increases are possible, but environmental effects preclude additional expansion over and above the 29-percent growth projected for hydro and geothermal power in OECD Europe.

ACCELERATED VERSUS BASE CASE

The OECD study projects that a vigorous conservation policy, coupled with an aggressive supply policy, could reduce oil imports significantly in OECD Europe. The accelerated scenario projects a 5-percent additional reduction of demand, or 85 Mtoe (about 1.7 million bbl/d) for all of OECD Europe by 1985.

Supply in the accelerated scenario could be increased by: 26.2 Mtoe of natural gas (about 0. 5 million bbl/d) and 38.4 Mtoe of nuclear capacity (about 0. 8 million bbl/d). Additional coal imports of 19.2 Mtoe could replace about 400,000 bbl/d of oil imports. Total savings from conservation, coal imports, and domestic supply additions are estimated at 180. 3 Mtoe (or about 3.6 million bbl/d).

JAPAN

Japan has hardly any oil and natural gas prospects within its own territory, and coal production is not expected to increase in the next decade. Deficiencies in domestic fuel production are projected to be made up by vast increases in nuclear power capacity and oil and LNG imports.

GDP growth rates are projected at 6 percent annually to 1980, and 6.6 percent a year from 1980–85. Higher prices and Government conservation policy is projected to bring the energy/GDP ratio down to 0.94 in the reference scenario. OECD projects that additional energy savings of 4 percent a year can be achieved without harming economic growth. These additional savings are incorporated in the accelerated scenario.

ENERGY SUPPLY

A tenfold increase of nuclear power capacity is projected for 1985 (reference case). The accelerated scenario calls for an almost fifteenfold increase by 1985 (over 1974). The base case projects a nuclear power capacity of 35.1 GWe in 1985; the accelerated case calls for a capacity of 49 GWe.

Potential constraints on nuclear power expansion: environmental (thermal pollution, earthquake potential, powerplant siting). Oil and coal will have to substitute any shortfall in nuclear power capacity. Oil-fired stations involve less pollution and can be built more quickly than coal-fired plants. For this reason OECD decided to choose oil plants to make up for the nuclear shortfall in the base case.

In view of the almost negligible oil and gas production in Japan, oil, gas, and coal imports are projected to rise steadily. Oil imports in the base case rise from 5.3 to 8.8 million bbl/d. Natural gas imports increase from 5.7 billion cubic meters (0.2 TCF) in 1974 to 26 billion (0.9 TCF) in 1980 and 46 billion (1.6 TCF) in 1985. Coal imports are projected to rise from 64.6 million metric tons in 1974 to 86.5 million in 1980 and 98.4 million tons by 1985.

WORLD DEMAND FOR OPEC OIL

The OECD outlook demand for OPEC oil by 1985 is as follows:

Countries:	*Million barrels per day*
United States	9. 7
OECD Europe	14. 7
Japan	8. 8
Other developed countries	. 8
OPEC domestic demand	3. 5
Bunkers	. 7
Changes in stocks	. 5
Other	. 6
Total demand for OPEC oil	39. 3

TABLE 5.—PROJECTED WORLD OIL TRADE, NET IMPORTS (+)/EXPORTS (–)

[Mtoe (Mb/d)]

					1985			
	1974		1980		Reference case		Accelerated policy case	
Canada	–9	(–0.2)	38	(0.8)	54	(1.1)	35	(0.7)
United States	290	(5.9)	458	(9.3)	477	(9.7)	211	(4.3)
OECD Europe	708	(14.2)	624	(12.4)	738	(14.7)	554	(11.0)
Japan	263	(5.2)	348	(6.9)	441	(8.7)	382	(7.6)
Australia/New Zealand	14	(.3)	30	(.6)	40	(.8)	35	(.7)
Total OECD	1,266	(25.3)	1,498	(30.0)	1,750	(35.0)	1,218	(24.4)
Centrally planned Europe	–14	(–.8)	–25	(–.5)	20	(.4)	20	(.4)
Centrally planned Asia	–7	(–.1)	–25	(–.5)	–60	(–1.2)	–60	(–1.2)
Oil importing developing countries	161	(3.2)	148	(2.9)	149	(3.0)	149	(3.0)
Other countries	39	(.8)	57	(1.1)	61	(1.2)	61	(1.2)
Non-OPEC oil exporting developing countries	–46	(–.9)	–150	(–3.0)	–189	(–3.8)	–189	(–3.8)
Residual [1]	72	(1.4)	25	(.5)	25	(.5)	25	(.5)
Total net import demand	1,444	(28.9)	1,528	(30.6)	1,756	(35.1)	1,224	(24.5)
OPEC consumption [2]	97	(1.9)	146	(2.9)	208	(4.2)	204	(4.1)
OPEC production	1,541	(30.8)	1,674	(33.5)	1,964	(39.3)	1,428	(28.6)

[1] Change in stocks at sea and statistical difference.
[2] Includes bunkers.

TABLE 6.—WORLD DEMAND FOR OPEC OIL IN 1974, 1980 AND 1985

[Mtoe (M b/d)]

	1974		1980		1985	
1. Non-OPEC demand	1,372	(27.4)	1,503	(30.1)	[1] 1,731 [2] 1,199	(34.6) (24.2)
2. Change in floating stocks [3]	72	(1.4)	25	(.5)	25	(.5)
3. OPEC net exports (3 = 1 + 2)	1,444	(28.9)	1,528	(30.6)	[1] 1,756 [2] 1,224	(35.1) (24.5)
4. OPEC bunkers	25	(.5)	30	(.6)	[1] 34 [2] 30	(.7) (.6)
5. OPEC inland demand	72	(1.4)	116	(2.3)	174	(3.5)
6. Total demand for OPEC oil (6 = 3 + 4 ÷ 5)	1,541	(30.8)	1,676	(33.5)	[1] 1,964 [2] 1,428	(39.3) (28.6)
7. Productive capacity		(35.6)		(45.0)		(45.0)
8. Underutilization of capacity		(4.8)		(11.5)		[1] (5.7) [2] (16.4)

[1] OECD reference case.
[2] OECD accelerated policy case (1985 obly).
[3] Includes statistical differences for 1974.

Productive capacity of OPEC is estimated at 45 million barrels per day in 1985, leaving a surplus capacity of 5.7 million barrels per day. In 1980, world demand for OPEC is projected at 33.5 million barrels per day; productive capacity is estimated at 45 million barrels per day; and, surplus capacity in 1980 would be 11.5 million barrels per day. About two-thirds of the surplus capacity is held by Saudi Arabia alone, which will reinforce that country's position within OPEC. Iraq and Iran are also projected to have increased their underutilized capacity by the early 1980's even though their need for revenue to finance development will be great. Other OPEC countries will be producing at capacity or near capacity by 1980. The OECD reports makes clear that countries may not produce at capacity or near that level. The marginal cost of creating and maintaining excess capacity is low and some excess capacity may be intentionally planned in the hope that it will confer political power.

ENERGY DEMAND AND SUPPLY: 1985–90

The OECD report recognizes that trend extrapolations beyond 1985 are increasingly subject to error. By 1990 new forms of energy may be quite significant, but at present these are only in the R. & D. stage.

Recognizing the limitations of the forecast, the OECD report assumes economic growth rates of 4.1 percent annually between 1985 and 1990. About 20 percent more energy will be consumed in 1990 than in 1985, and much of the expansion in supply will be coal and nuclear power. Oil import demand by 1990 for the entire OECD region is projected at 40.5 million barrels per day, or 5.5 million barrels per day more than in 1985. The increase is rather evenly distributed among North America, Japan, and Europe. In the accelerated development case, oil imports in the OECD region would be limited to 27.2 million barrels per day, or slightly above the 1973 level.

Higher or lower economic growth rates will have an important impact on energy consumption. If, for example, actual economic growth rates will be one-half of 1 percent higher or lower than the 4.2 percent assumed here, oil imports in the OECD may deviate 5 million to 10 million barrels per day either direction from the above 1990 estimate.

On the supply side, possible new finds in the North Sea, uncertainty about the future of nuclear power and about the coal option, will also effect oil imports. Synfuels and solar energy are expected to make a small contribution by 1990, but high costs and long leadtimes for large commercial production will limit contribution from those sources. Only early technological breakthroughs leading to large reductions in costs could change this outlook.

ENERGY PROSPECT TO 1995

If no changes take place in economic growth, energy conservation, oil pricing, resources discovery or technological developments, energy consumption in 1995 will be 20 percent more than the 1990 rate of consumption. OECD admits that this is a naive case. The outlook to 1995 was touched, however, to show the seriousness of the long-term energy situation under such circumstances. North Sea oil from reserves proved ln 1975 would have peaked, and even if nuclear capacity grew at a rate of 10 percent per year it would do no more than meet the growth increment in the OECD. Because the future of the breeder reactor, fusion, geothermal and solar energy, are uncertain, these sources of energy were not discussed in the OECD outlook. The scenario to 1995 suggests world oil demand to surpass supply, resulting in upward pressure on the price of oil.

TABLE 7.—OIL DEMAND AND SUPPLY PROJECTIONS, FREE WORLD

[Million b/d]

	1976	1977	1978	1979	1980	1985
Free world oil demand	48.4	49.8–50.5	51.2–52.2	52.5–54.1	54.9–56.7	68.3–72.6
United States	16.7	17.8–18.3	18.2–19.0	18.4–19.7	19.3–20.7	22.2–25.6
OECD Europe	13.6	13.9–14.3	13.8–14.2	13.7.14.4	13.7–14.7	15.8–18.2
Japan	5.2	5.3–5.4	5.5–5.8	5.9–6.2	6.2–6.6	8.1–8.8
Canada	2.0	2.0–2.1	2.1–2.2	2.2–2.3	2.2–2.4	2.9–3.5
Other developed countries [1]	1.2	1.2	1.3	1.3	1.4	1.9
Non-OPEC LDC's	6.7	7.1	7.5	7.8	8.5	12.0
OPEC countries	2.1	2.3	2.5	2.8	3.0	4.0
Other demand [2]	.9	0	0	0	0	0
Non-OPEC supply [3]	17.5	18.5	20.1	21.2	22.0	20.4–22.4
United States	9.7	9.6	10.2	10.2	10.0	10.0–11.0
OECD Europe	.9	1.8	2.5	3.1	3.7	4.0–5.0
Japan	0	0	0	0	0	.1
Canada	1.6	1.6	1.5	1.5	1.5	1.3–1.5
Other developed countries [1]	.5	.5	.5	.5	.5	.4
Non-OPEC LDC's	3.7	4.1	4.6	5.3	6.1	8.0–9.0
Net Communist trade:						
U.S.S.R.-Eastern Europe	.9	.7	.5	.2	−.3	−3.5 −4.5
China	.2	.2	.3	.4	.5	0
Required OPEC production	30.9	31.3–32.0	31.1–32.1	31.3–32.9	32.9–34.7	47.6–51.2

[1] Australia, Israel, New Zealand, and South Africa.
[2] Including stock changes and statistical discrepancy.
[3] Including natural gas liquids.

TABLE 8.—PRODUCTION CAPACITY PROJECTIONS, OPEC COUNTRIES (EXCLUDING SAUDI ARABIA)

[Million b/d]

	March 1977	1980	1985
Total	26.8	27.6–28.3	27.5–29.4
Algeria	1.0	1.0	0.9–1.1
Ecuador	.2	.2	.2
Gabon	.2	.2	.2
Indonesia	1.7	1.9–2.1	1.6–2.1
Iran	6.7	6.5	5.5–6.5
Iraq	3.0	4.5	5.0–6.0
Kuwait	3.5	3.0	3.0
Libya	2.5	2.5	2.0–2.5
Nigeria	2.3	2.3	2.0–3.0
Qatar	.7	.7	.5
United Arab Emirates	2.4	2.5–3.2	3.0–3.5
Venezuela	2.6	2.2–2.4	2.2

SOVIET ENERGY PROSPECTS

The Soviet plan calls for oil production by 1980 of 620 Mtoe (12.4 million barrels per day). The OECD estimates a Soviet oil production of 580 Mtoe (11.6 million barrels per day) in 1980 and 625 Mtoe (12.5 million barrels per day) by 1985. To achieve this rate of production (up from 9.8 million barrels per day in 1976), Western aid would be needed.

Soviet oil consumption is estimated at 460 Mtoe (9.2 million barrels per day) in 1980, and exports at 140 Mtoe (2.8 million barrels per day) by 1985. About one-half would be exported to Eastern Europe and the other half to the West in exchange for hard currency. Eastern Europe's growing needs for imported oil would be partially offset by higher natural gas imports (substitute fuel) from the U.S.S.R. Eastern Europe's oil imports of 81 Mtoe (1.6 million barrels per day) in 1974 are projected to increase to 110 Mtoe (2.2 million barrels per day) in 1980 and 140 Mtoe (2.8 million barrels per day) by 1985.

Chinese oil exports reached 200,000 barrels per day in 1976 and are expected to increase in the future; 1980 oil exports are projected at 500,000 to 600,000 barrels per day, rising to 1.2 million barrels per day by 1985. Constraint on oil exports are: Need for the oil at home, ideology, high capital costs (the Chinese may not be willing to buy vast quantities of Western equipment and depend on foreign assistance to develop their outer continental shelf).

EXXON, "WORLD ENERGY OUTLOOK", 1977

Economic growth in the United States, Western Europe, and Japan is not expected to return to the 1953–73 trend of 4.5 percent annual growth rates. For the period from 1975–80 growth rates are estimated to average 4.3 percent; for the decade of the 1980's, average annual growth rates of 3.7 percent are projected. Lower growth rates reflect declining productivity of capital, which is related to expenditures for environmental improvements, more expensive energy than in the past, and the continuing depletion and increasing cost of natural resources; persistent balance of payments strains, partly related to labor cost pressures and the many demands on governments for social services. The growth rate could be further reduced if real prices rise significantly.

CONSERVATION

Higher prices and mandatory conservations have already had an impact on energy conservation. It is projected that further reductions in the energy/GNP ratio will occur in the years ahead.

From 1965–73 when economic growth rates in the OECD averaged 4.7 percent per year, energy growth rates averaged 5.1 percent. For 1975–80 this is expected to change. With economic growth rates estimated at 4.3 percent for the period, annual average energy growth rates are estimated at 4 percent. For 1980–90, 3.7 percent economic growth rates per annum would require energy growth rates of 3.1 percent.

The difference between the historical and the projected relationship between energy and GNP is equivalent to a savings of about 22 million barrels per day by 1990.

WORLD ENERGY DEMAND

The estimated economic growth rates in the free world would require the following average annual energy growth rates:

AVERAGE GROWTH IN ENERGY DEMAND

[Percent per year]

	1975–80	1980–90
United States	3.6	2.8
Europe	4.2	3.4
Japan	5.4	4.0
Other	6.7	5.9
Total	4.6	3.9

The long-term rate of 3.9 percent per year is well below the pre-1973 trend projection of over 5 percent per year. Slower economic growth rates and conservation are the prime reasons for the lower energy growth rates. The difference between the current estimated and the pre-1973 experience adds up to about 60 million bbl/d additional world energy demand by 1990.

Free world energy consumption is expected to grow from about 85 million bbl/d oil equivalent in 1975 to 157 million bbl/d oil equivalent in 1990. The fastest growth will be in the developing nations—40 percent of total growth in world demand.

WORLD ENERGY SUPPLY

Total world nonoil supply, which grew 3.2 percent per annum between 1965 and 1973, is projected to grow at annual rates of 4.1 percent between 1975 and 1980, and at 5.2 percent during the decade of the 1980's.

Oil supply, which grew at the high annual rate of 7.7 percent between 1965 and 1973, is estimated to grow at annual rates of 5.5 percent between 1975 and 1980, and at 2.5 percent between 1980 and 1990.

Oil

Free world oil supply is projected to grow from 46 million bbl/d in 1975 to 76 million bbl/d by 1990. Achievement of this target will depend on the level of exploration activities, finding rates, and OPEC ability and willingness to produce.

Most of the increased non-OPEC oil production is expected to come from Europe (North Sea), Mexico, and Alaska.

Requirement for OPEC oil is projected to grow from 28 million bbl/d in 1975 to 38 million bbl/d in 1980; 42 million bbl/d in 1985; and, 46 million bbl/d by 1990.

The attainability of these volumes of supply and the willingness of key Middle East countries to produce their reserves at the rates projected are major uncertainties of the outlook.

About one-third of the 1990 production will have to come from oil resources that have not yet been discovered.

OIL IMPORT REQUIREMENTS

[In millions of barrels per day]

	1975	1980	1985	1990
United States	6.0	12.1	12.5	11.4
Europe	12.8	13.0	13.5	14.9
Japan	5.0	6.2	7.1	8.0
Total	23.8	31.3	33.1	34.3

Within OPEC, major production expansion can only be expected in the Arabian Peninsula, where about half of the world's oil reserves are located. Production restrictions in these countries could mean a very tight demand/supply balance.

Natural gas

Free world natural gas consumption is expected to grow from 16 million barrels per day oil equivalent in 1975 (about 32 tcf/year) to 23 million barrels per day oil equivalent in 1990—about 46 tcf/year. Whether these projections will be achieved will depend largely on discovery rates in industrial countries and on LNG policies of exporting and importing countries.

The United States is the only industrial country where the share of natural gas in the total energy supply is likely to decline. In Europe, production is projected to grow through the middle 1980's, when production is likely to peak. In the Middle East local consumptions and exports are likely to lead to increased gas utilization.

TOTAL FREE WORLD GAS SUPPLY

[In trillions of cubic feet per year]

	1975		1990	
	Local	Imports	Local	Imports
United States	19.7	0.9	15.1	2.0
Canada	2.6	(.9)	5.0	(.9)
Europe	5.9	.5	8.5	4.2
Japan	.1	.2	.2	1.8
Other	3.8	(.8)	18.2	(6.3)
Total	32.1		47.0	

Coal

Coal is essentially demand limited, but in many areas an aggressive supply policy is needed to meet development targets.

In the non-Communist world, coal supply is estimated to grow from 1,346 million tons in 1975 to 2,000 million tons in 1985, and 2,500 million tons by the year 1990 (see (fig. 2).

Nuclear power

In spite of the numerous obstacles and uncertainties, nuclear power is still one of the fastest growing areas of world energy supply.

INSTALLED CAPACITY

[In gigawatts]

	1975	1980	1985	1990
United States	34	80	160	260
Europe	19	55	115	220
Japan	5	15	40	60
Other	4	15	36	70
Total	67	165	350	610

In this study nuclear power is projected to grow at a rate of 17 percent per year, a tenfold increase (see fig. 3).

The 1976 Exxon studies shows that nuclear projections declined compared with 1973 and 1975 studies (see fig. 4). Compared with the 1973 analysis, 1985's expected nuclear output was reduced by almost 35 percent. Various problems such as uncertainty of electricity demand, construction costs, financing problems, sitting, environmental and other constraints are responsible for the downward revision.

Exxon 1978 Outlook

Exxon is in the process of updating its 1977 world energy outlook. GNP growth rates have been revised downward and so have energy growth rates.

TABLE 1.—EXXON 1976 AND 1977 GNP AND ENERGY DEMAND FORECASTS

[In percent]

	1975–80	1980–90
Exxon 1977 free world GNP growth rate	4.3	3.5
Exxon 1977 free world energy demand growth rate	4.6	4.0
Exxon 1978 free world GNP growth rate	3.5	3.7
Exxon 1978 free world energy demand growth rate	3.9	3.5

TABLE 2.—AVERAGE ENERGY GROWTH

[Percent per year (by region)]

	1975–80		1980–90	
	1977 study	1978 study	1977 study	1978 study
United States	3.6	2.6	2.8	2.3
Europe	4.2	3.2	3.4	2.9
Japan	5.4	5.5	4.0	3.9
Other	6.7	6.3	5.9	5.5
Total	4.6	3.9	3.9	3.5

World energy supply has been adjusted downward in the 1978 study.

TABLE 3.—FREE WORLD OIL SUPPLY

[In millions of barrels per day]

	1980		1985		1990	
	1977 study	1978 study	1977 study	1978 study	1977 study	1978 study
United States and Canada	11	11	11	11	13	11
Europe	3	3	5	5	6	6
Other non-OPEC	6	6	9	8	10	10
OPEC–ME	28	25	32	30	37	34
Other	10	10	10	10	9	10
Net imports	1	1	1	1	1	1
Total	59	56	68	65	76	72

World natural gas supply has been revised downward slightly compared with the 1977 study. Most of the downward revision is due to lower estimates of U.S. natural gas production.

World coal supply has been revised upward slightly in the 1978 study for both 1985 and 1990 (about 5 percent higher coal use than the 1977 study).

Nuclear power capacity has been revised downward significantly for 1985 and 1990.

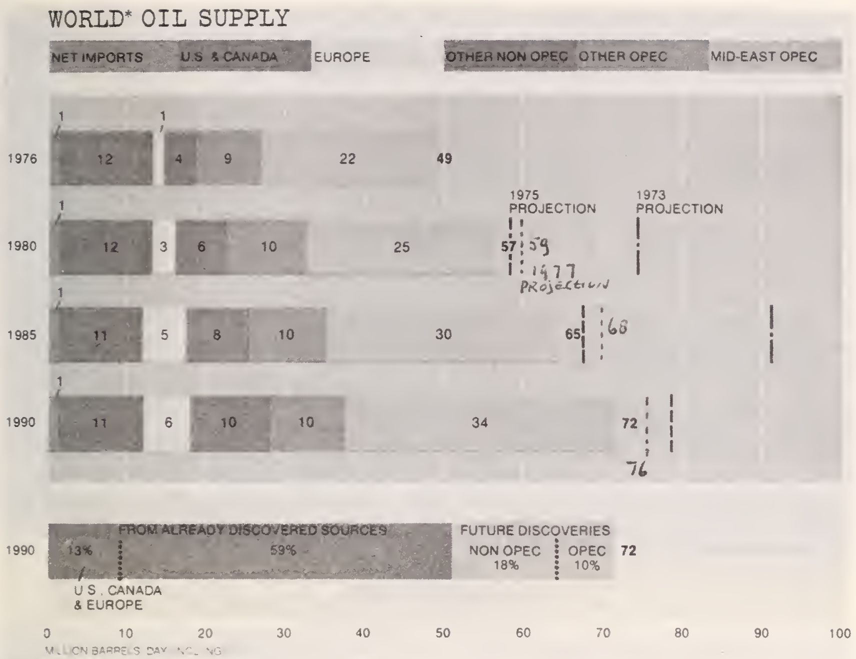
TABLE 4.—INSTALLED NUCLEAR CAPACITY

[In gigawatts]

	1980		1985		1990	
	1977 study	1978 study	1977 study	1978 study	1977 study	1978 study
United States	80	72	160	135	260	190
Europe	55	52	115	90	220	160
Japan	15	15	40	30	60	50
Other	15	11	35	35	70	55
Total	165	150	350	290	610	445

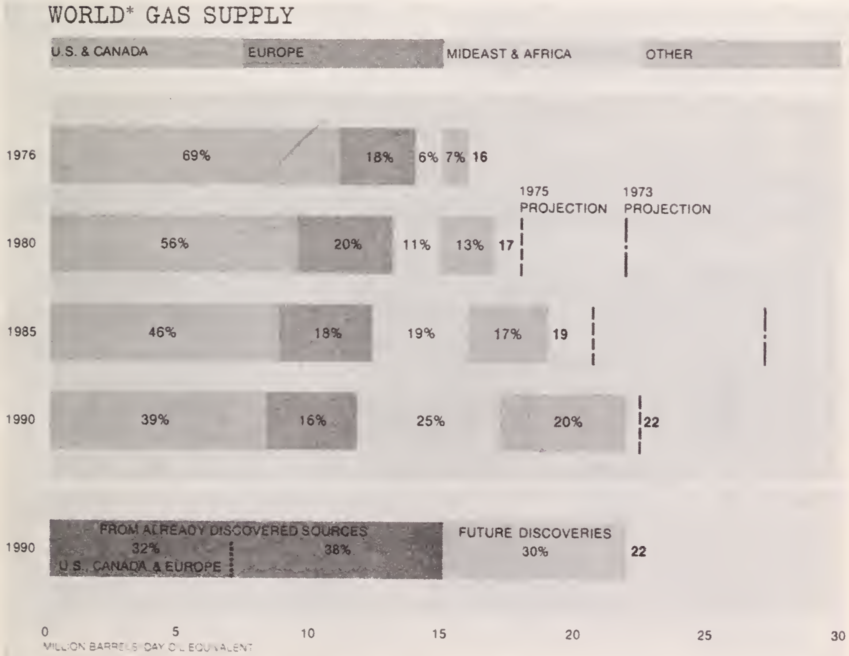
Finally, the 1978 study suggests that the world outlook for the development of new energy sources is not very promising.

FIGURE 1



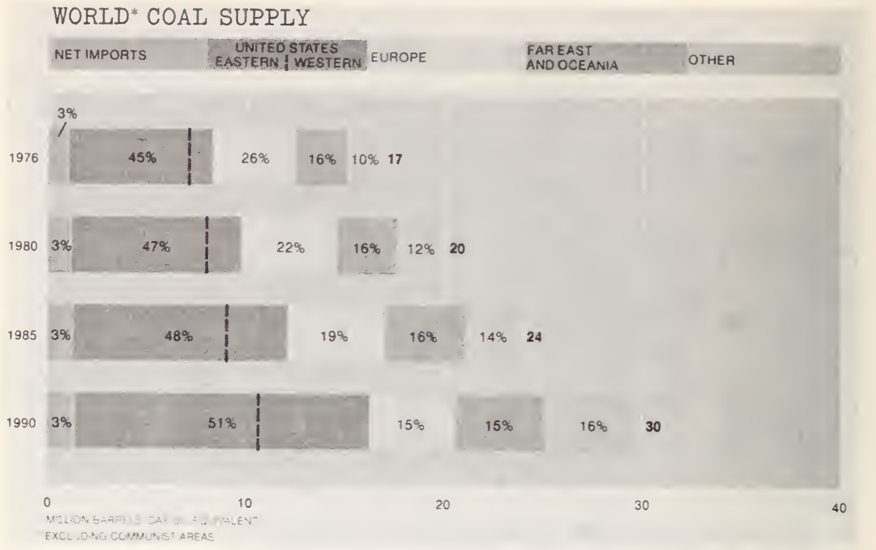
*EXCLUDING COMMUNIST AREAS

FIGURE 2



*EXCLUDING COMMUNIST AREAS

FIGURE 3



COAL SUPPLY BY AREA

[In millions of short tons per year]

	1976	1980	1985	1990
Total	1,395	1,615	2,090	2,690
United States	670	830	1,090	1,520
Europe	360	360	375	380
Far East, Oceania	220	255	315	360
Other	145	170	310	430

Note: Includes net imports from Communist area.

FIGURE 4

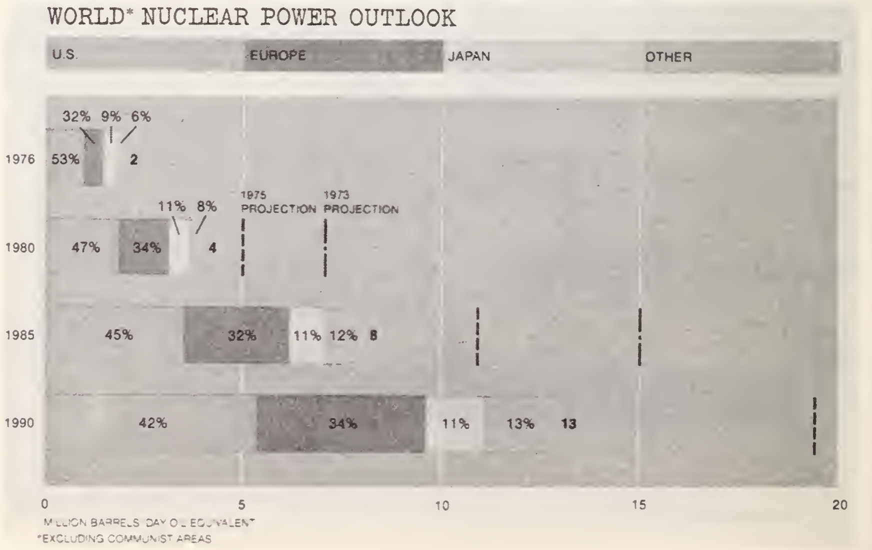


FIGURE 5

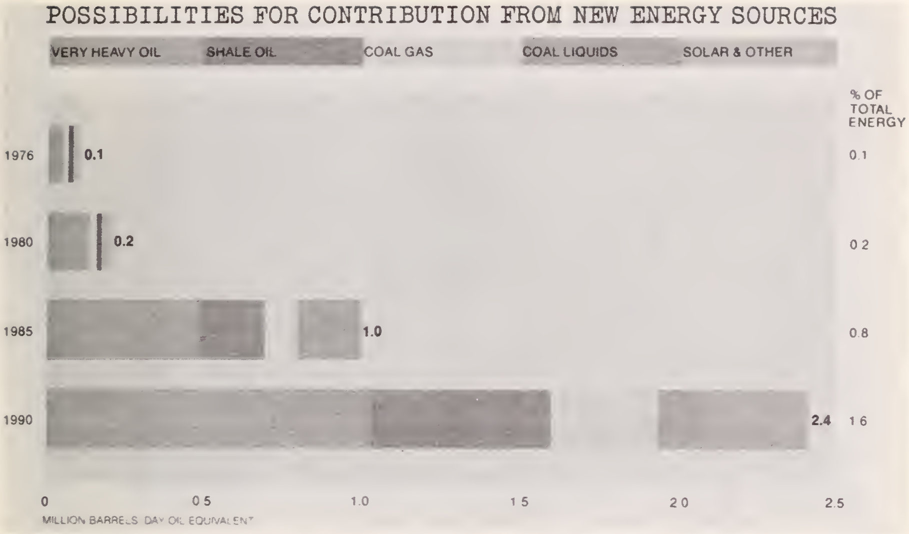
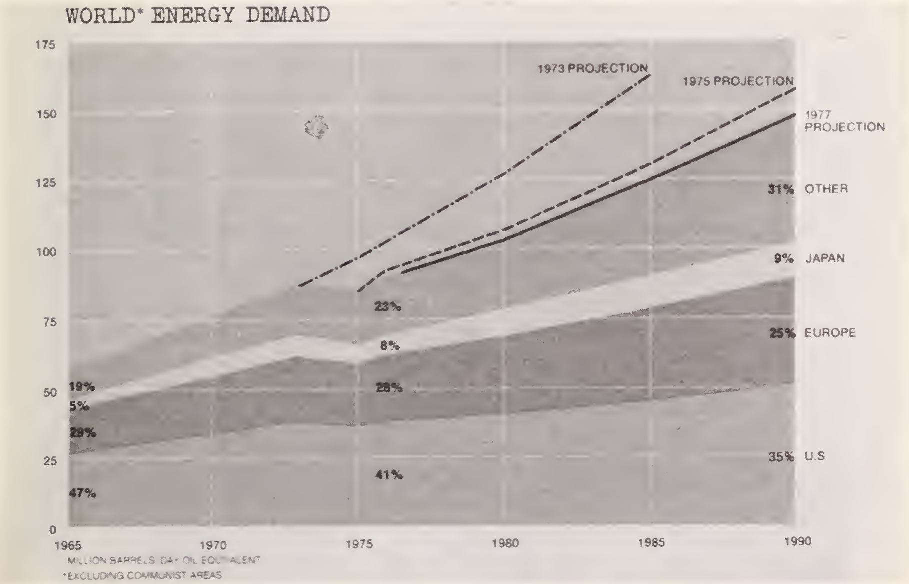


FIGURE 6



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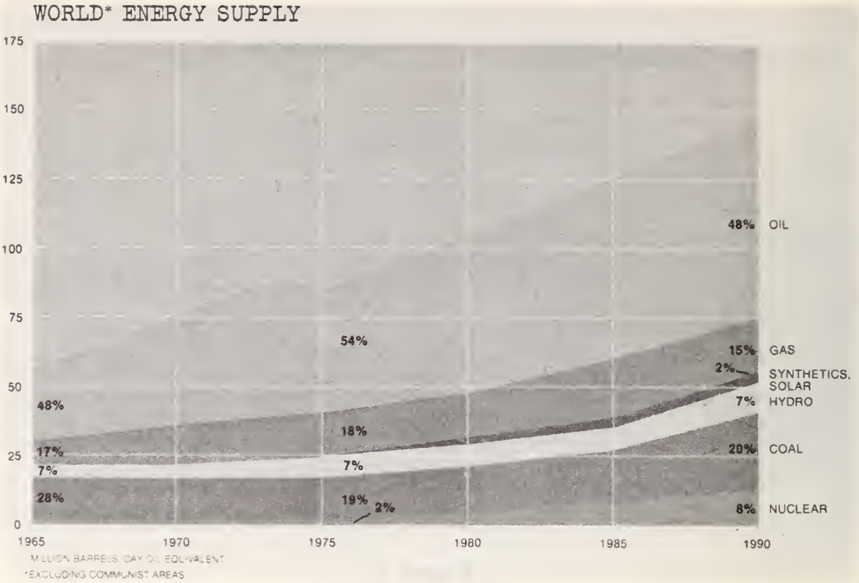


FIGURE 8

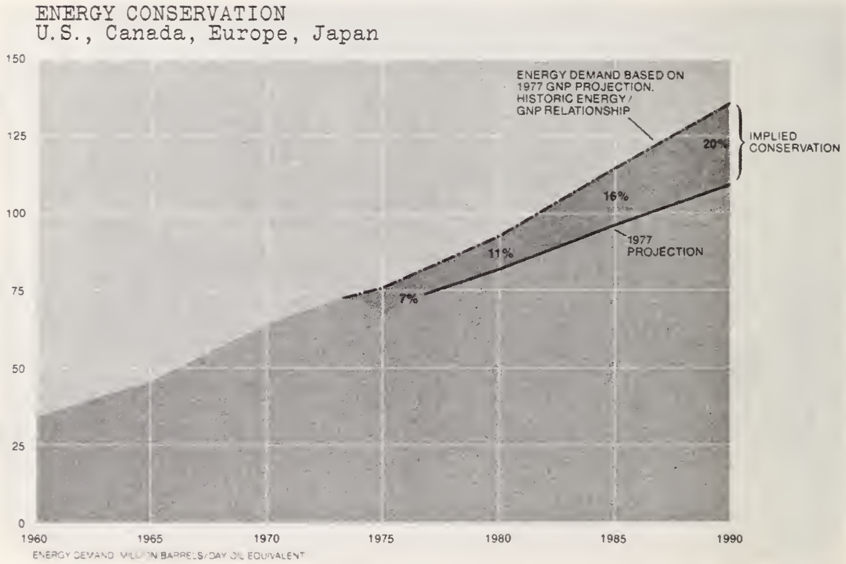
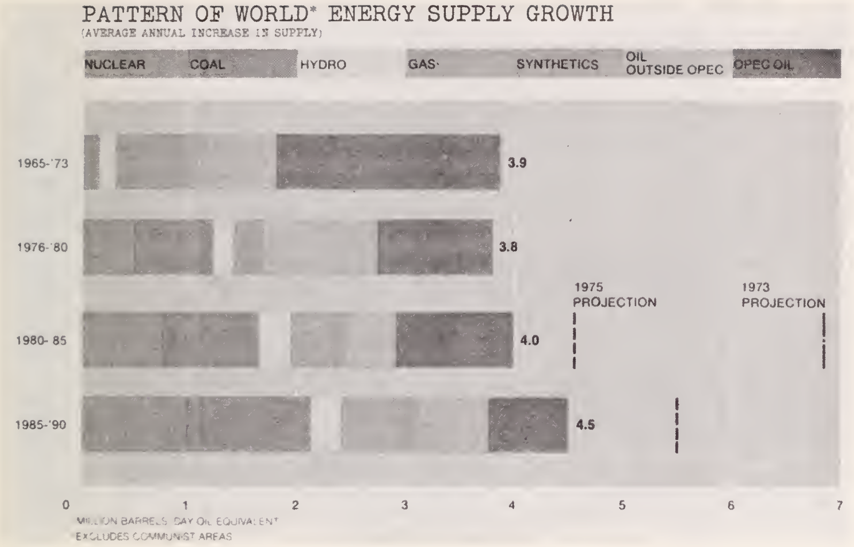
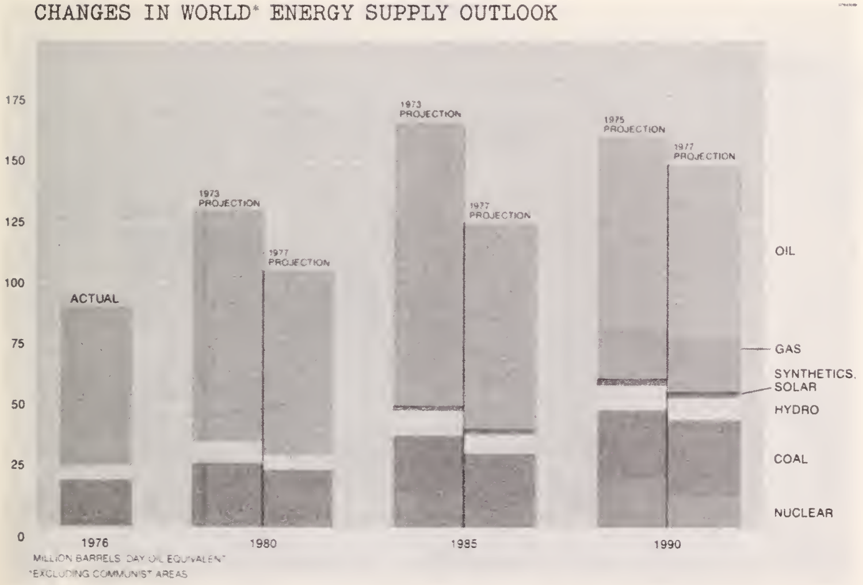


FIGURE 9



PATTERN OF WORLD* ENERGY SUPPLY GROWTH

(AVERAGE ANNUAL INCREASE IN SUPPLY)



CHANGES IN WORLD* ENERGY SUPPLY OUTLOOK

FIGURE 10

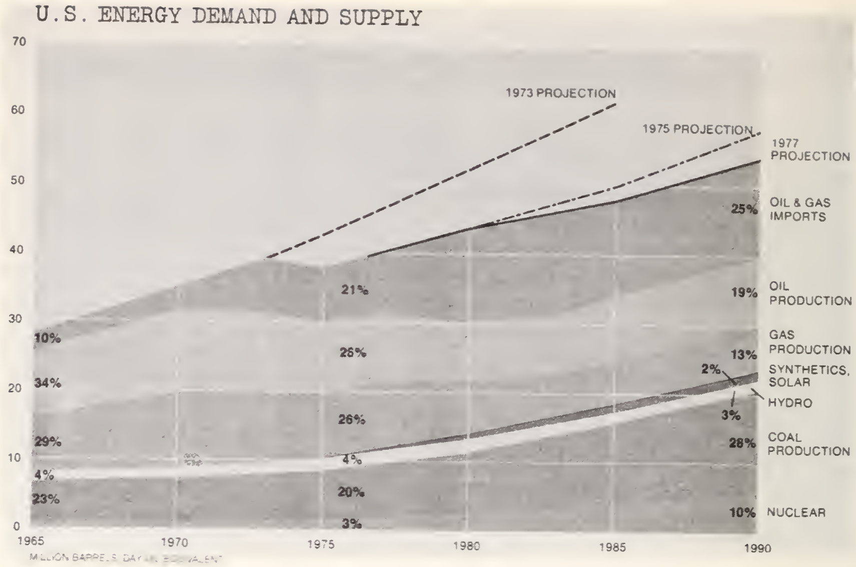


FIGURE 11

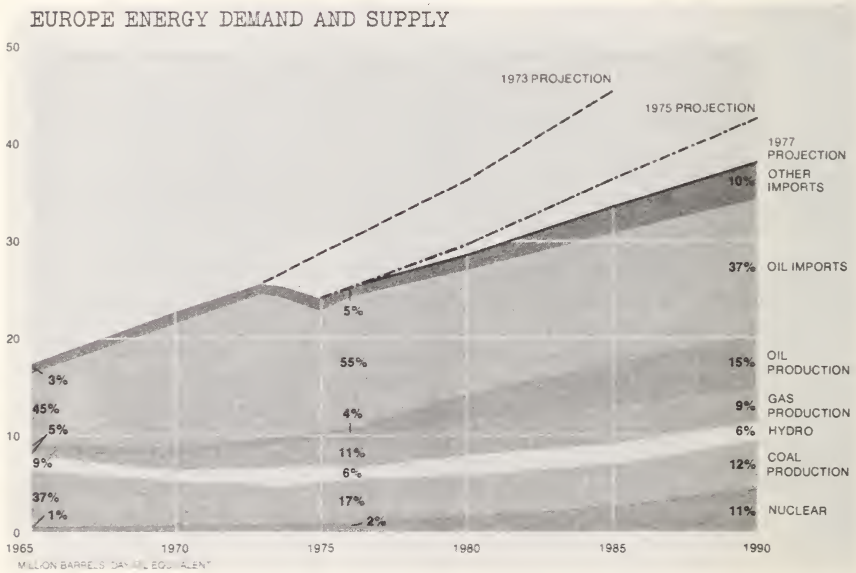


FIGURE 12

JAPAN ENERGY DEMAND AND SUPPLY

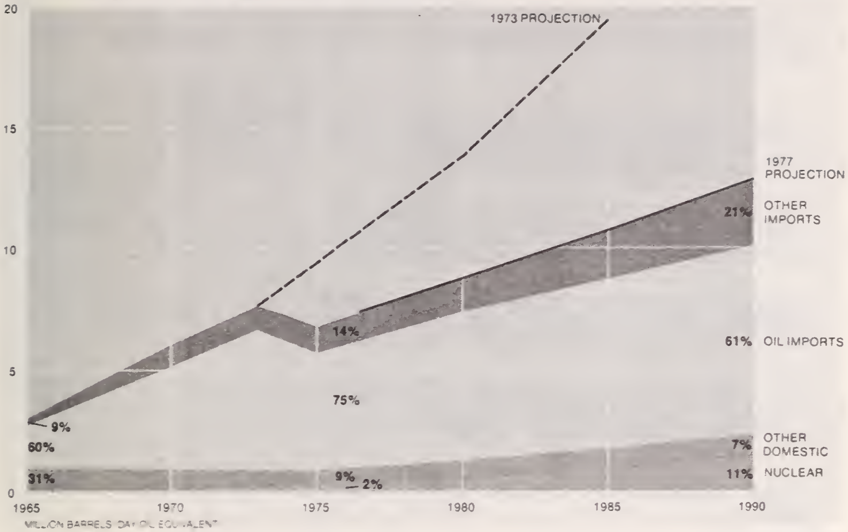


FIGURE 13

WORLD* OIL DEMAND AND SUPPLY

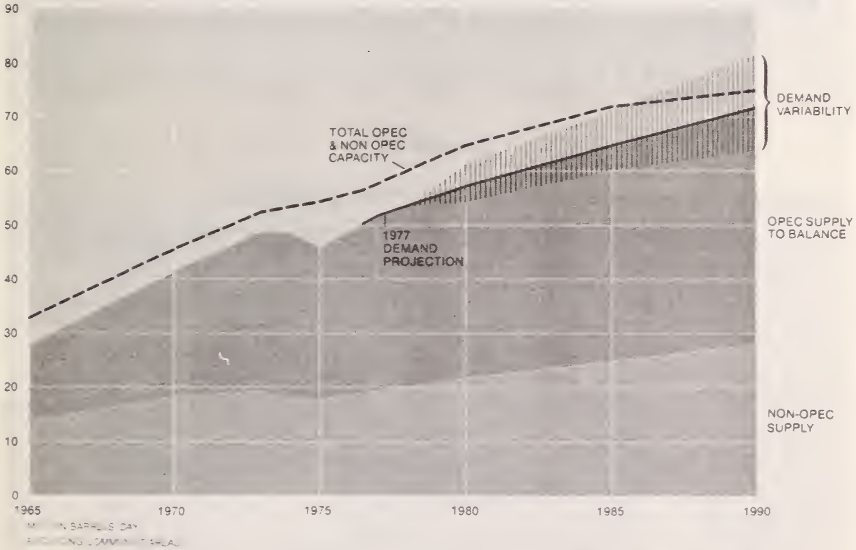


FIGURE 14

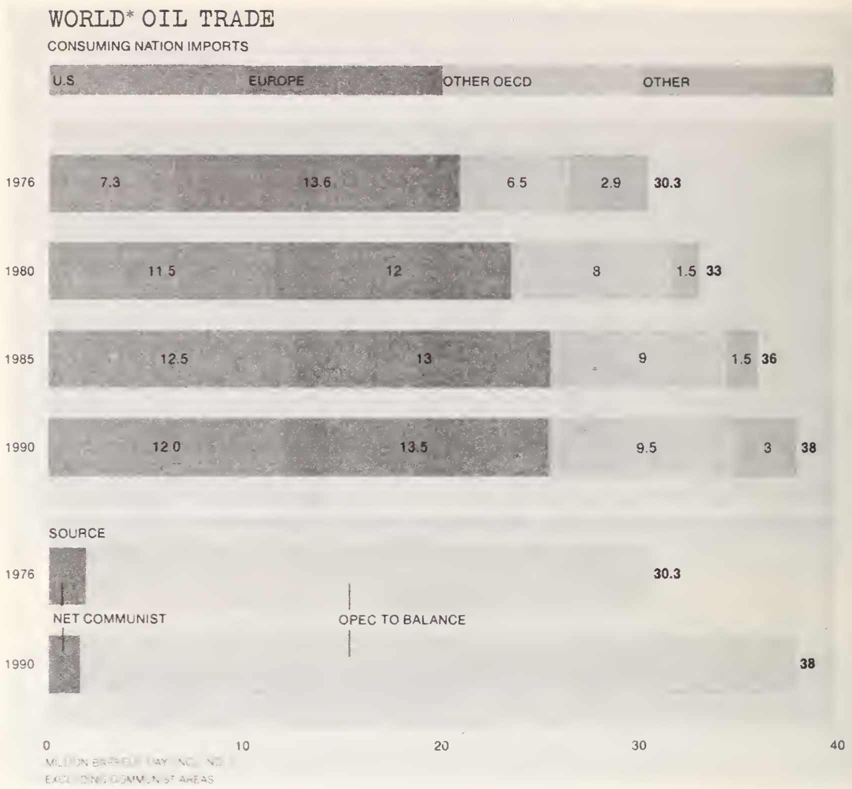


FIGURE 15

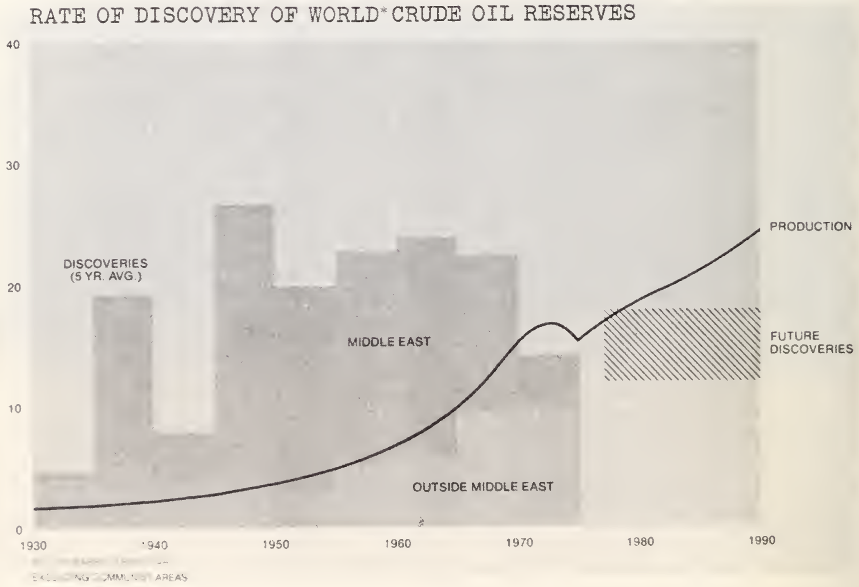
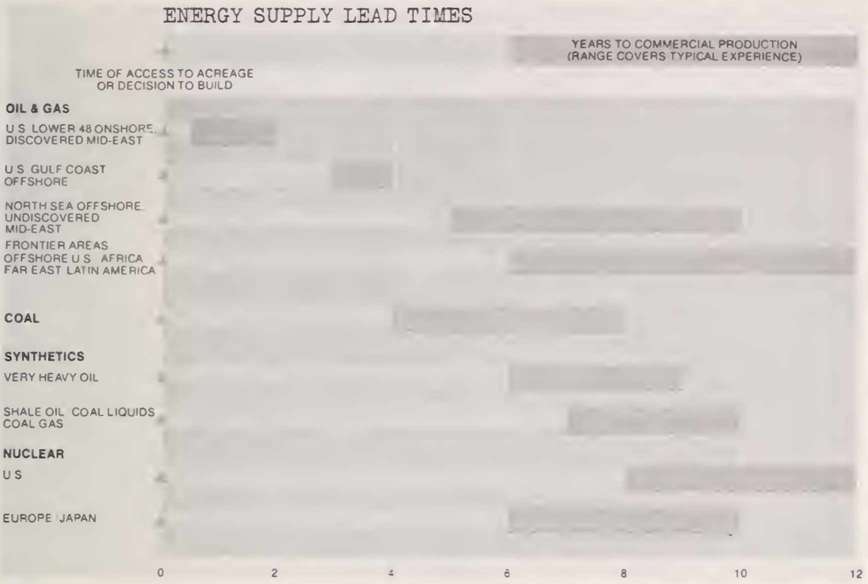


FIGURE 16


ENERGY SUPPLY LEAD TIMES
YEARS TO COMMERCIAL PRODUCTION (RANGE COVERS TYPICAL EXPERIENCE)
TIME OF ACCESS TO ACREAGE OR DECISION TO BUILD
OIL & GAS
U S LOWER 48 ONSHORE, DISCOVERED MID-EAST
U S GULF COAST OFFSHORE
NORTH SEA OFFSHORE, UNDISCOVERED MID-EAST
FRONTIER AREAS OFFSHORE U S AFRICA FAR EAST LATIN AMERICA
COAL
SYNTHETICS
VERY HEAVY OIL
SHALE OIL COAL LIQUIDS COAL GAS
NUCLEAR
U S
EUROPE JAPAN
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